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# HE USE OF SEDATIVES TO REDUCE MANIPULATIVE ERROR IN MEASURING FISH[1]

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ABSTRACT

Repeated fork and total length measurements were taken on sample lots ve fish each from four different groups of living fish. The fish were then ged with urethane and the measurements repeated. The following informa- was obtained. (1) Although reductions in manipulative error were found stically significant in half the comparisons, an analysis of the sample sizes rugged and of normal fish that would be required to give the same accuracy onstrated that even the significant reductions would be of little practical e. (2) Measurements of drugged fish were not significantly longer than e of normal fish for either fork or total lengths, and fork and total length surements were found essentially equal in accuracy. (3) Under the condi- s of this study, anesthetization did not appreciably shorten the time required easure fish.

Use of sedatives in fishery work is increasing. Literature on this ect indicates that such drugs may have certain advantages. fiths *et al.* (1941) found that adult steelhead trout were easily vned when anesthetized in a 1.5 to 2.0 per cent aqueous solution ther. The eggs obtained showed a lower mortality than those n by conventional stripping. Johnson (1954) saved time taking from brook trout treated with urethane with no adverse effects he hatch. Foster (1941) noted greater speed and accuracy in ping, fewer injuries to fish, and less fatigue to workers in marking inch cutthroat trout. Eschmeyer (1953) found the use of ether thesia decidely a time saver in marking fingerling lake trout, by ng the slower markers especially.

In a discussion following a paper by DeRoche and Bond (1955) possibility of difference in length measurements of drugged and ormal fish was mentioned. These workers noted that some of the

e author is indebted to Dr. D. A. Webster, Associate Professor of Fishery logy, Cornell University, who suggested this study and assisted in prepara- n of the manuscript. R. W. Hatch, P. C. Neth, and R. W. Wahl, graduate dents at Cornell University, assisted in the study. Fish were provided by New York State Conservation Department, the United States Fish and ldlife Service, and the Department of Conservation, Cornell University. D. S. Robson, Assistant Professor of Biological Statistics, Cornell Uni- sity, offered statistical counsel and reviewed the manuscript.

lengths of fish recaptured after tagging were apparently shorter th those of the same fish when they were tagged while drugged. T discussion prompted the present study to provide information on following points: (1) possible difference in length measureme between normal and drugged fish; (2) possible difference in the p cision of measurement of fork and total lengths between normal a drugged fish.

Although a fish at any one time has one definite fork length a one definite total length, repeated measurements on any specim will show variation. This variation is due partly to manipulative er and partly to adjustments in technique and such temporal effects tiring of both fish and operator.

Manipulative error is defined in this paper as variation amo repeated measurements of fork and total lengths taken on the sa five fish, with the temporal effects of trials removed.

## PROCEDURE

Sample lots of five fish each were obtained as follows:

Lot 1—Brown trout yearlings (7.7 to 9.3 inches in total leng from U. S. Fish and Wildlife Service Hatchery, Cortla New York.

Lot 2—Lake trout yearlings (5.4 to 7.5 inches in total leng from New York State Fish Hatchery, Bath, New Yo

Lot 3—Pikeperch adults (15.7 to 16.8 inches in total leng from Oneida Lake, held for fish cultural purposes at New York State Fish Hatchery, Constantia, New Yo

Lot 4—Lake trout adults (25.4 to 28.1 inches in total leng from Cayuga Lake, gill netted for tagging by the Depa ment of Conservation, Cornell University.

During measurement the fish in each lot, except the adult l trout, were placed in five separate holding nets enumerated one five. The adult lake trout were held in a live bag and distinguish by a clipped fin. An assistant handed the fish in haphazard order the operator who measured both fork and total lengths and return the fish to the assistant. This process continued until five trials w completed for each of the five fish in the lot. The same fish w then drugged and the measurements repeated.

Measurements were made to the nearest 0.1 inch for the ad fish, and to the nearest millimeter for the yearling fish. Any consci

ort to measure fish more accurately than is usually done in the d was avoided. All measurements were made by the author. Time uired to measure the five fish in both the normal and drugged es was recorded.

The fish were drugged in a 0.5 per cent solution of urethane until y were completely relaxed, as indicated by all fish in the sample ng unable to right themselves when turned on their sides. From o 5 minutes were required to produce this condition, with the larger taking the longer time. Urethane is now widely recognized as arcinogen, and its use is curtailed. But other sedatives are com-nly used, and the principle of this study remains valid.

## EFFECT OF SEDATIVES ON MANIPULATIVE ERROR

Fork length measurements for yearling brown trout are given in ble 1. The analysis of variance for these data is given in Table 2.

LE 1. FORK LENGTH MEASUREMENTS (IN MILLIMETERS) FOR YEARLING BROWN TROUT

| Trial | Fish | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| | Normal | | | | |
| 1 | 198 | 190 | 192 | 230 | 200 |
| 2 | 196 | 189 | 191 | 229 | 201 |
| 3 | 198 | 190 | 190 | 232 | 202 |
| 4 | 200 | 190 | 191 | 232 | 204 |
| 5 | 198 | 189 | 190 | 231 | 202 |
| | Drugged | | | | |
| 1 | 200 | 189 | 193 | 232 | 202 |
| 2 | 199 | 189 | 190 | 232 | 202 |
| 3 | 199 | 189 | 192 | 231 | 202 |
| 4 | 199 | 189 | 189 | 232 | 201 |
| 5 | 199 | 189 | 190 | 229 | 202 |

e that variation between trials, and variation between fish of differ-sizes, have been removed. The particular $F$-test used here is not conventional comparison of experimental error variance with treat-t variance. Rather, here the manipulative error variance for normal is compared with the manipulative error variance for drugged fish. $F$-test is "one-tailed", i.e., we only wished to determine whether

TABLE 2. ANALYSIS OF VARIANCE OF THE DATA FOR YEARLING BROWN TRO PRESENTED IN TABLE 1*

| Source variation | Degrees of freedom | Standard deviation | |
|---|---|---|---|
| | | Sum | Mean |
| **Normal** | | | |
| Between fish | 4 | 5,622.4 | 1,405.6 |
| Between trials | 4 | 12.8 | 3.20 |
| Manipulative error | 16 | 14.8 | 0.92 |
| **Drugged** | | | |
| Between fish | 4 | 5,770.8 | 1,442.7 |
| Between trials | 4 | 6.0 | 1.500 |
| Manipulative error | 16 | 13.2 | 0.825 |

$$* F = \frac{0.925}{0.825} = 1.12$$

TABLE 3. MANIPULATIVE ERROR VARIANCES AND *F*-VALUES FOR THE EIG COMPARISONS

| Fish | Fork length | | | Total length | | |
|---|---|---|---|---|---|---|
| | Manipulative error variance | | *F*-value | Manipulative error variance | | *F*-valu |
| | Normal | Drugged | | Normal | Drugged | |
| Brown trout yearlings | 0.925 | 0.825 | 1.12 | 1.038 | 0.538 | 1.93 |
| Lake trout yearlings | 0.913 | 0.262 | 3.48** | 1.363 | 0.275 | 4.96** |
| Pikeperch adults | 0.0031 | 0.0025 | 1.24 | 0.0025 | 0.0031 | .. |
| Lake trout adults | 0.0025 | 0.0006 | 4.17** | 0.0056 | 0.0006 | 9.33** |

** Significant at the one per cent level; $F = 2.94$, with 16 degrees of freedo

the manipulative error was significantly *lower* for the drugged fis Consequently the *F*-test is $\frac{\text{normal manipulative error variance}}{\text{drugged manipulative error variance}}$.

Variances and the appropriate *F*-values for the eight possib comparisons among the four groups of fish are presented in Table The results indicate that drugging produced significant reductio in manipulative error for both fork and total lengths in lake tro

arlings and adults. In the data for total length of pikeperch adults, anipulative error variance among drugged fish was greater than at among normal fish, and no *F*-value was calculated. The other ree comparisons did not demonstrate significant reductions.

Although statistically significant reductions were shown in four tances, a further analysis was made to determine whether these ductions had any practical value. This was done by calculating the mple size of normal fish that would be required to give the same curacy (i.e., same variance of a sample mean) as a sample of 100 igged fish. The statistical method employed for this analysis was apted from Snedecor (1946, Chapter 10) by Dr. D. S. Robson, sistant Professor of Biological Statistics, Cornell University.

It was found that the addition of just one more fish per 100 in normal fish sample compensated in accuracy for the reduction in anipulative error caused by drugging the fish. Thus, even in lake ut adults measured for total lengths where the reduction was highly nificant, a sample of 101 normal fish gave the same accuracy as ample of 100 drugged fish.

The conclusion drawn from this analysis is that reductions in anipulative error, as represented by data for the four groups of igged fish, would be of little practical value.

## BIAS IN MEASURING DRUGGED AND NORMAL FISH

Drugged fish are relaxed fish, and the possibility exists that longer asurements were obtained when the fish were drugged. The original

BLE 4. FORK LENGTH MEASUREMENTS OF LAKE TROUT YEARLINGS SUMMARIZED FOR ANALYSIS OF BIAS IN MEASURING NORMAL AND DRUGGED FISH*

| Fish | Normal | Drugged |
|---|---|---|
| 1 | 636 | 639 |
| 2 | 704 | 705 |
| 3 | 771 | 771 |
| 4 | 882 | 877 |
| 5 | 685 | 690 |
| Total | 3,678 | 3,682 |

* Measurements in millimeters.

TABLE 5. ANALYSIS OF VARIANCE OF THE DATA FOR LAKE TROUT YEARLI SUMMARIZED IN TABLE 4

| Source of variation | Degrees of freedom | Standard deviation | | *F*-val |
|---|---|---|---|---|
| | | Sum | Mean | |
| Between fish | 4 | 69,728.0 | .. | .. |
| Drugged *vs* normal fish | 1 | 1.6 | 1.6 | 0.2 |
| Residual | 4 | 28.4 | 7.1 | .. |
| Total | 9 | 69,758.0 | .. | .. |

data, summarized in a slightly different manner, can be tested such a bias. Data for the fork length of lake trout yearlings are s marized in Table 4. The analysis of variance for these data is gi in Table 5. The *F*-value is not significant at the 5 per cent level.

None of the remaining comparisons showed significant *F*-va either. This indicates that measurements of drugged fish were significantly longer than those of normal fish and that they w probably not biased for this reason.

## ACCURACY OF FORK VERSUS TOTAL LENGTH MEASUREMEN

Working with perch, crappies, and pikeperch, Carlander Smith (1945) concluded that in general the mean of the stand deviations of measurements for each fish in their samples was usu lower for total length than for fork or various standard length meas ments.

In the present study, standard deviations for both lengths w calculated for each group of undrugged fish with variation attribut to the effects of trials and differences in fish size in each sam removed. In the case of pikeperch adults, the standard deviation total length measurements was lower than that for fork lengths. in the other three groups of fish, fork length measurements were variable than those for total length. However, *F*-tests demonstra that these differences between variances (standard deviation squar of the two measurements were not significant in all four groups. other words, the accuracies of fork length and total length meas ments in each of the four groups of fish were essentially the sa Variances, standard deviations, and *F*-values used in these anal are presented in Table 6.

BLE 6. STANDARD DEVIATIONS, VARIANCES, AND *F*-VALUES USED IN COMPARING THE ACCURACIES OF FORK AND TOTAL LENGTH MEASUREMENTS OF UNDRUGGED FISH

| Fish | Length measurement | Standard deviation | Variance | *F*-value |
|---|---|---|---|---|
| wn trout earlings* | Fork | 0.962 | 0.925 | 1.122 |
| | Total | 1.012 | 1.038 | |
| e trout earlings* | Fork | 0.956 | 0.913 | 1.493 |
| | Total | 1.168 | 1.363 | |
| perch dults§ | Fork | 0.056 | 0.0031 | 1.240 |
| | Total | 0.050 | 0.0025 | |
| e trout dults§ | Fork | 0.050 | 0.0025 | 2.240 |
| | Total | 0.075 | 0.0056 | |

Measured to the nearest millimeter.
Measured to the nearest 0.1 inch.

## TIME REQUIRED FOR MEASUREMENTS

The total time required to measure all four groups of normal fish 0 fork lengths and 100 total lengths) was 25 minutes and 47 sec- s. The total time for drugged fish was 20 minutes and 18 seconds, eduction of about 20 per cent. To the latter must be added the e required for anesthetization. If all fish had been treated at the e time, it would have taken at least 5 minutes, the time required ompletely relax the lake trout adults. Actually, when anesthetiza- time is included, very little time was saved in these tests by drug- the fish.

In other field procedures involving extensive handling of each (e.g., stripping, tagging, or weighing on pan scales) use of seda- s may involve significant time saving as well as other advantages. Oregon Game Commission (1950) found that anesthetization ced tagging time by 31 per cent (they did not indicate that time treatment was considered). They also found a slightly higher sur- l for fish tagged while under an anesthetic than for fish tagged out such treatment.

Measurements were taken in this study under good working con- ns. When field conditions adversely influence the time required andle fish, and also the manipulative error in measuring them, tives may be an aid.

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# RLY BIOCHEMICAL CHANGES IN THE SOILS AND WATERS OF ARTIFICALLY CREATED MARSHES IN NEW YORK[1]

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## ABSTRACT

Shallow-water environments were studied over a 2-year period in six ificially-created marshes. Special attention was given to site selection, chem- y of the soils of the drainage areas and of the marsh basins. In addition, nges in marsh soil chemistry following flooding or drainage were evaluated conjunction with data for thermal and chemical stratification of the water.

Site selection based on herbaceous vegetation prior to flooding could not related to productivity of the flooded site. Submergence of woody vegeta- n, which was killed by flooding, resulted in water of lower transparency, l woody material on the marsh floor reduced the area available for plant wth.

Marshes surrounded by good agricultural soils were more productive of d and cover plants than those surrounded by degraded lands.

Soil analysis, except for certain of the trace elements, indicated that soils marsh basins were more fertile, *per se*, than those of the contiguous drainage as. Excessive concentrations of soluble iron and manganese were noted.

Strong thermal and chemical stratification was noted in the water of rshes studied.

Data, when related to marsh management, point to possible dangers of quent drainage and the need for removing surface as opposed to subsurface ers in a normal plan for handling excess runoff.

Drainage, to be effective, must result in aeration of marsh soils. In this r, organic matter may be sharply reduced and the capacity of the environ- nt to produce conditions for the solution of iron and manganese in excessive centrations thereby inhibited.

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Hubert Maguire, New York State Conservation Department, aided greatly valuating mathematically part of the data.

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In particular, we are indebted to Professor John C. Ayers, University of higan (formerly of Cornell University), whose generous and wise counsel direct field assistance guided our entire program.

Fertilization of marshes with the usual fertilizer elements (nitrog phosphorus and potash) would seem unnecessary. Liming with calcium a magnesium as monocarbonates may be of singular importance for regulat pH for maintaining nutrient salt balances, for effecting a stronger bu system, and as an aid in maintaining favorable transparency of the water.

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In the Northeast the need for managing fresh water has b forcibly imposed on the consciousness of the general public by rec ring droughts and floods. The costly consequences of such conditi could and should result in increased efforts to retain on the lan larger part of the annual precipitation, the loss of which as run has reduced agricultural productivity and overtaxed natural a artificial water channels. One of the several interdependent me of reducing floods and alleviating some of the adverse influences drought is to develop numerous small, headwater impoundments.

Such areas, in addition to their essential role in water mana ment, may function to improve the general environment for wildl and specifically the habitat for waterfowl and some of the fur-bear mammals. For these species, productivity of a large proportion of artificially-created, shallow-water impoundments developed in N York State has diminished with time. A similar pattern has ch acterized some of the larger bodies of water created by the Fed Government.

What conditions, brought on by flooding, militate against continuance of a suitable environment? A partial answer to question may be found in knowledge gained in the production of l land rice. Growers of this crop have increased yields by the judici application of fertilizers, by the regulation of soil pH, and by fallow their fields. Such measures suggest that the performance of submer soils in producing rooted aquatic plants is related to the availabi of and the balance between nutrient salts. Thus it seemed that initial investigation into problems of marsh management should concerned with the intrinsic concentrations of essential elements the soils of marsh basins and contiguous drainage areas, and with amounts of these essential salts which become available for assimilat by plants.

The study reported here was initiated in April 1953 and pertai to created marshes in which water depths were not greater than 3 f for at least 75 per cent of the flooded area. Further, it invol marshes developed on heavy soils in areas of the State where ann rainfall was not less than 36 inches.

## PROCEDURE

The investigation was predicated on the assumption that a fuller preciation of the forces which may inhibit the productivity of rooted atic plants on flooded lands could be gained by studying the s both before and after flooding. As a check on this hypothesis, reverse procedure, i.e., studying changes associated with removal water from soils which had been flooded for several years, was luded. To facilitate understanding changes in the soils, certain sical and chemical properties of the overlying water were also estigated. These generalized approaches, then, represent the broad n of study. A more specific treatment of procedures follows.

### lection of Study Areas

Lands which it is practical to flood are frequently poorly drained. accumulation of organic matter is thus to be expected; water- osited soil may often be noted in the soil profile, and products reduction may be detected except for brief periods during the driest t of the summer. In selecting study sites, those having these char- eristics should yield information of the broadest application. ther, sites selected should be relatively free from the influences agriculture. When drainage areas are intensively farmed, runoff l seepage water from such lands may carry exceptionally large ounts of nutrient salts and thus tend to mask the natural relation- os under consideration. Lastly, the soil types studied should repre- t, by and large, those on which marshes have been developed and which future water areas are likely to be created. Accordingly, following study areas were selected: the Swartwood Marsh, the ure Farmers of America Marsh, and four water areas on State- ned Howland's Island Game Management Area.

The Swartwood Marsh is located at West Danby in Tompkins unty at an elevation of 900 feet above sea level. A 15-acre artificial oundment, it lies within the bed of ancient Lake Ithaca and thus h of its drainage is composed of lacustrine soils of the Dunkirk s. Approximately 14 per cent of the drainage area was wet land, per cent was cultivated, 23 per cent was in pasture, and the remain- 53 per cent was in secondgrowth woodlands (Figure 1). This was flooded for the first time in the spring of 1954.

The Future Farmers of America Marsh (hereafter designated as A.) is located about 2 miles south of the village of Spencer in ga County, at an elevation of 1,680 feet. Prior to flooding in the

Figure 1. Site of Swartwood Marsh before flooding.

Figure 2. F F A Marsh just after flooding.

ter of 1954, the marsh basin was a poorly drained depression ounded by impoverished Volusia clay and silty-clay soils. Agricul- had ceased at least a decade before. The entire drainage area reverted from pasture to an overgrown environment with aspen *pulus tremuloides*), thornapple (*Crataegus* sp.), azalea (*Rhodo-dron nudiflorum*), common low blueberry (*Vaccinium vacillans*), l apple (*Malus* sp.) and a scattering of white pine (*Pinus strobus*) ng the more common species present. The flooded area covers acres (Figure 2).

Howland's Island is situated approximately 4 miles northwest Port Byron in Cayuga County. The Island proper is formed by Barge Canal and the Seneca River. Soils are represented by ario silt loam, stony phase. These highly productive, glacial till are characterized by limestone deposits throughout their profile are generally favorable for agriculture. The topography varies gently rolling to steep. The drainage areas of the study sites with one exception, too steep for farming; consequently, the vege-on is either grassland, brush or small woodlots (Figure 3). The ation of the study areas is 400 feet.

Figure 3. Pond 5A at Howland's Island Game Management Area.

Study sites at Howland's Island had been flooded in 1934. records were kept of site characteristics prior to flooding and, as was desirable to obtain an understanding of these conditions, a poo drained but unflooded section of the drainage immediately adjace to one pond (5A) was investigated (Figure 4). This section receiv runoff from soils which were comparable to those of the drainage a of Pond 5A.

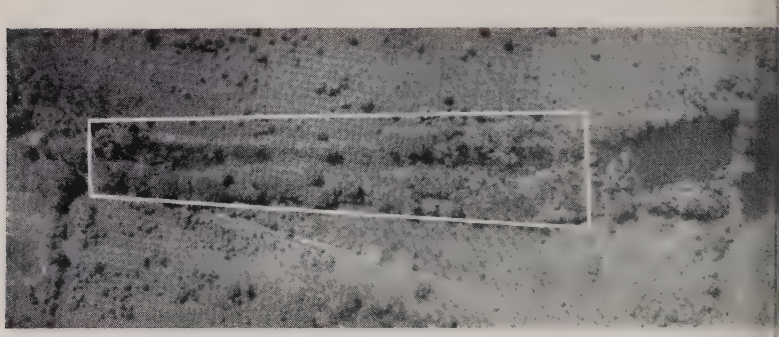


Figure 4. Unflooded drainage adjacent to Pond 5A.

Changes in the concentration of nutrient salts were studied Pond 5A for summer drainage and at Pond 18 for fall-winter draina Changes in water chemistry during the winter were studied at Po 14 and 15.

### Collection of Data

Data on the character of marsh basin soils prior to flooding a on changes which occurred in the soil and water following submerge were obtained from the Swartwood and F.F.A. Marshes. On H land's Island, the site adjacent to Pond 5A furnished data conside to be representative of that pond before it was flooded. Data rela to soils submerged for 10 or more years were derived from Ponds and 18.

Plant collections were made at each site throughout the per of study. Specimens collected were labeled and preserved for re ence.

### Collection and Treatment of Soil Samples

At each site soil surveys were made of both the drainage a and marsh basin, except for Pond 18 at which no drainage area sam were obtained.

The general fertility level of drainage areas was determined by ing soil samples at 100-foot intervals along lines radiating from oint within the marsh basin to the top of the watershed. For each the Howland's Island and F.F.A. sites six such lines were estab- ed, whereas 12 lines were needed to sample the drainage area of Swartwood Marsh. Soil boring samples obtained along each line e mixed, air dried, and pulverized before analysis.

Soil samples from marsh basins proper, prior to flooding, were en at 100-foot intervals along the 1-foot contour and along a through the center of each basin. After flooding, samples were en at random points averaging eight per acre (Figures 5 and 6). the Swartwood Marsh it was impossible to obtain soil cores at of the 120 locations as the soil was in suspension for a depth greater n the length of the corer.

Samples from ponds to be drained (Ponds 5A and 18) were taken marked points along transects. Following drainage, samples were in taken at the same locations along these lines.

Samples of the imperfectly drained soils of the marsh basins, h before and after flooding, were handled in a manner different m that used for samples of dry soil of the drainage area. This necessary because chemical and/or biological activity after the rly drained soils were disturbed could have changed their com- ition to something quite different from that of the soil *in situ*. prevent or hold to a minimum such disturbances, soil samples his kind were frozen immediately after being obtained. Such sam- , in all instances, were taken with a coring device[2] which contained lastic liner for receiving the soil. After coring the liner was oved, stoppered at both ends, labeled, and either taken immedi- y to a portable deep-freeze unit or placed in an insulated container dry ice. The latter allowed the collection of 14 samples without rruption. Samples awaiting analysis were stored in a commercial zer.

To remove the frozen soil from its container, the whole was merged in hot water until the perifery of the soil melted. Then vas forced from the plastic tube with the aid of a steel disk on end of a tire pump plunger. The frozen core was then divided layers based on visual inspection of the organic matter content. these there were usually two, an organic one and a mineral one. e cores, however, had a distinct intermediate "horizon".

[2] veloped by W. Waldon and P. Butler, Woods Hole Oceanographic Institu- n at Woods Hole, Mass.

Soil samples were analyzed for percentage of organic matter, p phosphorus, nitrate and ammonia nitrogen, calcium, magnesium, po sium, manganese, iron, and aluminum. Results for concentrations these elements or their salts were recorded in parts per million. T analyses dealt with only those elements or compounds that were solution and were accomplished by methods proposed by Peech a English (1944).

## Physical and Chemical Properties of the Water

Dissolved oxygen, total alkalinity, temperature and water tra parency were investigated at the Swartwood and F.F.A. Mars during the summer and early fall in 1954 and 1955. Dissolved oxy and temperature measurements were taken during the winter from Howland's Island areas.

Ten sampling stations at the Swartwood Marsh and nine at F.F.A. Marsh were established at points selected to reveal accura existing water conditions (Figures 5 and 6). At Howland's Isl

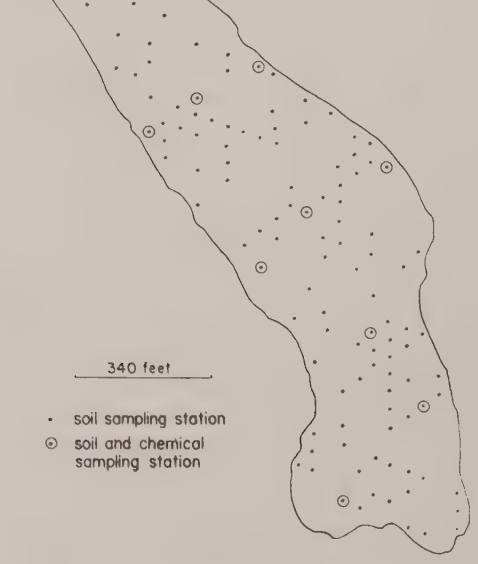



Figure 5. Sampling stations at the Swartwood Marsh.

ond 14) changes in water chemistry during the period of ice cover re noted at eight stations.

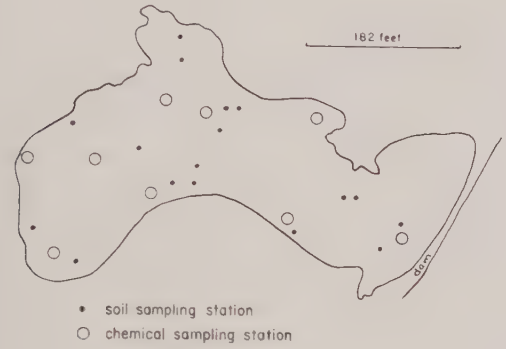
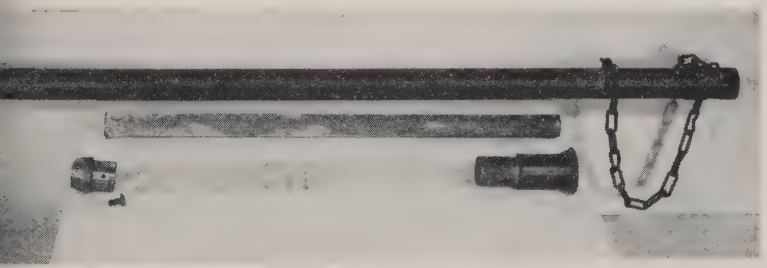



Figure 6. Sampling stations at the F.F.A. Marsh.

Oxygen samples were collected at vertical intervals of 1 foot inning at the surface, using a graduated rod to which was attached ength of rubber hose and a pump. Samples were collected in 300-liliter biochemical oxygen demand bottles which were overflowed ee times. The last overflow was pumped into an Erlenmeyer flask the temperature taken immediately with a stem thermometer. e dissolved oxygen content was determined by the basic Winkler hod when possible, but when orientation tests indicated the presence nterfering substances, the sample-blank modification of this tech-ue was used (Ellis *et al.*, 1948). Immediately following collec-, initial analytical reagents were added to the samples. Titration owed in the field after the collection and fixing of between 12 and



re 7. Soil coring device: (top) steel body of corer; (middle) metal spacer; (bottom, left to right) cutting head, pin for securing cutting head to body of corer, plastic tube for receiving soil core, driving head.

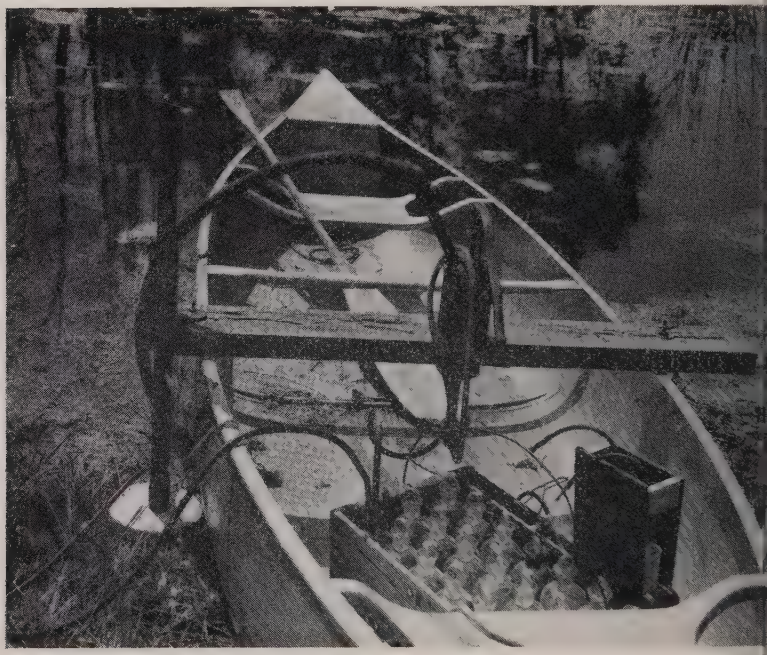


Figure 8. Arrangement of apparatus for securing water samples and deter ing water transparency.

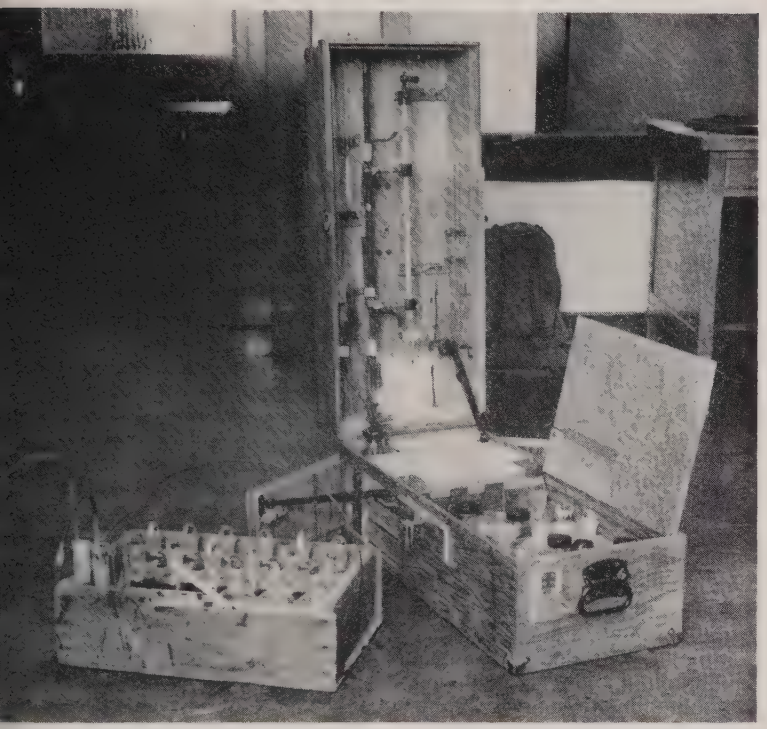
15 samples. Results were recorded in parts per million. Field eq ment is shown in Figures 7, 8 and 9.

Total alkalinity determinations were made by titrations 0.02N sulfuric acid using as indicators phenolphthalein and disod 4, 4′-bis (p-methylamino-phenylazo) -2, 2′ stilbenedisulfonate (Ta 1948). Collection of water samples for alkalinity determinat were made at the same depth intervals and with the same equipm as used for obtaining oxygen water samples. Titration was acc plished in the field by using a hypodermic syringe graduated in milliliters. Results were recorded in parts per million of calc carbonate.

To obtain data relative to diel (24-hour) changes in water t perature at different depths, a triple recording thermograph installed at the Swartwood Marsh.

## FINDINGS

Data presented have resulted from chemical analyses of soil



gure 9. Portable kit for determining concentrations of dissolved oxygen.

nage areas and of contiguous marsh basins before and after flood-
or before and after drainage, and from analyses of some of the
ical and chemical properties of the water of the marshes. Results
egetative changes concurrent with flooding are also presented as
general observations on the biology of these artifically created
ronments.

### etative Conditions Prior to Flooding

Intensive surveys were made of the Swartwood, F.F.A. and How-
's Island marsh development sites. The results are summarized in
les 1 and 2.

The Swartwood Marsh was pastured in 1953, the year prior to
ding. The F.F.A. site represented land which had been abandoned
at least a decade prior to 1954, while the Howland's Island site
not been used for agriculture for at least a quarter century prior
e study.

Table 1. Comparative Variety of Vegetation before Flooding at Three Marsh Sites Studied

| Marsh site | Families | Genera | Spe |
|---|---|---|---|
| Common to: | | | |
| Howland's Island, Swartwood and F.F.A. | 26 | 39 | |
| Howland's Island and Swartwood only | 12 | 16 | |
| Howland's Island and F.F.A. only | 2 | 4 | |
| Swartwood and F.F.A. only | 5 | 10 | |
| Howland's Island only | 3 | 12 | |
| Swartwood only | 2 | 21 | |
| F.F.A. only | 4 | 12 | |
| | 54 | 114 | 1 |

* Fewer species than genera appear in this category because certain g (e.g., *Prunus*) occurred at all sites while this was not true for any o species within them.

## Vegetative Conditions Prior to Drainage

Prior to drainage, Pond 5A at Howland's Island (Figure 3) tained no emergent vegetation except for a small stand of c *(Typha latifolia)* while three submerged species were present. I deeper portions, waterweed *(Anacharis canadensis)* covered mu the bottom with a few stems of curly-leaf pondweed *(Potamog crispis)* interspersed. This latter species increased in abundance to the shoreline. From approximately the 18-inch contour shorew sago pondweed *(Potamogeton pectinatus)* occurred sparingly. O submerged species present only waterweed had attained anything abundance.

## Vegetative Conditions After Drainage

Following drainage and soil aeration of the margins of Pon they produced a luxuriant growth of vegetation (Figure 10). At soil sampling station, exclusive of stations 7 and 8, six 1-foot were denuded of vegetation. This was air-dried and weighed. Sp composition varied with sedge *(Cyperus strigosus)* predominating the driest stations (1 and 2) grasses *(Eragrostis* sp. and *L oryzoides)* and spikerush *(Eleocharis* sp.) were present.

E 2. COMPARISON OF PLANT COMPOSITION ON THREE MARSH SITES PRIOR TO FLOODING

| Family and species | Howland's Island | Swartwood Marsh | F.F.A. Marsh |
|---|---|---|---|
| taceae | | | |
| *isetum arvense* | | | * |
| *ylvaticum* | * | * | * |
| odiaceae | | | |
| *opodium complanatum* | | | * |
| daceae | | | |
| *unda cinnamomea* | * | * | * |
| *aytoniana* | | | * |
| *galis* | * | | |
| diaceae | | | |
| *clea sensibilis* | * | * | * |
| *opteris cristata* | * | * | * |
| *helypteris* | | * | |
| *stichum acrostichoides* | * | | |
| *rium felix-femina* | * | * | * |
| *antum pedatum* | * | | |
| *idium aquilinum* | | | * |
| ae | | | |
| *ga canadensis* | | * | |
| *s strobus* | | | * |
| ceae | | | |
| *ha latifolia* | | * | * |
| taceae | | | |
| *ma plantago-aquatica* | | * | |
| aceae | | | |
| *pus atrovirens* | * | * | |
| *x brunnescens* | * | * | |
| *inita* | | * | |
| *bilis* | | * | |
| *acillima* | * | * | |
| *tumescens* | * | * | |
| *pulina* | * | * | |
| *rida* | * | | |
| *paria* | | * | |
| *oparia* | | * | |
| *ricta* | * | * | |
| *lldenowii* | | * | |
| *x* spp. | | * | |
| e | | | |
| *nema triphyllum* | * | * | * |
| *palustris* | | * | |
| *plocarpus foetidus* | * | | |
| ceae | | | |
| *na minor* | * | * | * |
| eae | | | |
| *us effusus* | | * | |
| *flexus* | * | * | |
| *la campestris* | | * | |
| ae | | | |
| *trum viride* | | * | |
| *aria sessilifolia* | | * | |
| *m canadense* | | * | |
| *nthemum canadense* | | * | |
| *ium grandiflorum* | | * | |
| *ax herbacea* | * | | |
| *spida* | | * | |
| ae | | | |
| *inchium angustifolium* | * | * | |

TABLE 2. COMPARISON OF PLANT COMPOSITION ON THREE MARSH SI PRIOR TO FLOODING—*(Continued)*

| Family and species | Howland's Island | Swartwood Marsh | F.F.A. Marsh |
|---|---|---|---|
| Salicaceae | | | |
| *Salix* sp. | * | * | * |
| *Populus tremuloides* | | * | * |
| Juglandaceae | | | |
| *Juglans cinerea* | * | * | |
| *Carya glabra* | | | * |
| Corylaceae | | | |
| *Carpinus caroliniana* | | * | * |
| *Betula lenta* | | * | |
| *B. lutea* | | * | |
| *Alnus rugosa* | | * | * |
| Fagaceae | | | |
| *Quercus alba* | | | * |
| *Q. rubra* | | | * |
| Ulmaceae | | | |
| *Ulmus americana* | * | * | |
| *U. rubra* | | * | |
| Urticaceae | | | |
| *Urtica procera* | * | | |
| *Laportea canadensis* | * | | |
| Polygonaceae | | | |
| *Rumex acetosella* | * | * | * |
| *R. britannica* | * | * | |
| *R. crispus* | * | * | |
| *Rumex* sp. | | | * |
| *Polygonum sagittatum* | | | * |
| *Polygonum* sp. | * | | |
| Caryophyllaceae | | | |
| *Stellaria longifolia* | | * | |
| *Cerastium vulgatum* | * | * | * |
| Ranunculaceae | | | |
| *Ranunculus abortivus* | | * | |
| *R. acris* | * | * | * |
| *R. repens* | | * | * |
| *Thalictrum polygamum* | | * | |
| *Clematis virginiana* | * | * | * |
| *Caltha palustris* | | * | |
| Berberidaceae | | | |
| *Podophyllum peltatum* | * | * | * |
| Lauraceae | | | |
| *Lindera benzoin* | * | * | |
| Cruciferae | | | |
| *Barbarea vulgaris* | * | | |
| Saxifragaceae | | | |
| *Tiarella cordifolia* | | | * |
| *Ribes americanum* | * | * | * |
| Hamamelidaceae | | | |
| *Hamamelis virginiana* | | | * |
| Rosaceae | | | |
| *Spiraea alba* | * | * | * |
| *Pyrus malus* | * | * | * |
| *P. melanocarpa* | | | * |
| *Amelanchier* sp. | | | * |
| *Crataegus* spp. | | * | * |
| *Fragaria virginiana* | * | * | * |
| *Potentilla recta* | * | | * |

LE 2. COMPARISON OF PLANT COMPOSITION ON THREE MARSH SITES PRIOR TO FLOODING—*(Continued)*

| Family and species | Howland's Island | Swartwood Marsh | F.F.A. Marsh |
|---|---|---|---|
| ceae—*Con't.* | | | |
| *um canadense* | | * | * |
| *rivale* | | | * |
| *virginianum* | | * | |
| *um* sp. | * | | |
| *bus allegheniensis* | * | * | * |
| *idaeus* | * | * | * |
| *occidentalis* | | * | |
| *pubescens* | * | * | |
| *a palustris* | * | | |
| *nus serotina* | * | | * |
| *virginiana* | * | * | |
| minosae | | | |
| *folium pratense* | | * | |
| *folium* sp. | * | * | * |
| *inia pseudo-acacia* | * | | |
| *phicarpa bracteata* | | * | * |
| daceae | | | |
| *alis* sp. | * | | * |
| iaceae | | | |
| *anium maculatum* | * | * | |
| ardiaceae | | | |
| *us toxicodendron* | * | * | * |
| *vernix* | * | | |
| oliaceae | | | |
| *verticillata* | * | * | * |
| ceae | | | |
| *ry nigrum* | | * | |
| *pennsylvanicum* | | | * |
| *rubrum* | * | * | * |
| *saccharum* | | * | |
| minaceae | | | |
| *patiens capensis* | | * | |
| eae | | | |
| *thenocissus quinquefolia* | * | * | |
| *is* sp. | * | | |
| eae | | | |
| *ia americana* | * | * | |
| ceae | | | |
| *la cucullata* | | | * |
| *la* sp. | * | | * |
| aceae | | | |
| *hrum salicaria* | * | * | * |
| lliferae | | | |
| *Brocolyle americana* | | * | |
| *ium maculatum* | | * | |
| *ata maculata* | | * | * |
| *m suave* | * | * | |
| *linaca sativa* | | | * |
| *ucus carota* | * | * | * |
| ceae | | | |
| *nus amomum* | * | * | |
| *acemosa* | | | * |
| eae | | | |
| *cinium angustifolium* | | * | * |
| *corymbosum* | | * | |

TABLE 2. COMPARISON OF PLANT COMPOSITION ON THREE MARSH S
PRIOR TO FLOODING—*(Concluded)*

| Family and species | Howland's Island | Swartwood Marsh | F.F.A. Marsh |
|---|---|---|---|
| Primulaceae | | | |
| *Lysimachia quadrifolia* | | | * |
| Oleaceae | | | |
| *Fraxinus americana* | | | * |
| *F. nigra* | * | * | |
| Apocynaceae | | | |
| *Apocynum cannabimum* | | * | * |
| Asclepiadaceae | | | |
| *Asclepias incarnata* | * | * | |
| *A. syriaca* | * | | |
| Boraginaceae | | | |
| *Cynoglossum officinale* | * | | |
| Labiatae | | | |
| *Prunella vulgaris* | * | * | * |
| *Satureja vulgaris* | | * | |
| Solanaceae | | | |
| *Solanum dulcamara* | * | * | |
| Scrophulariaceae | | | |
| *Veronica officinalis* | | * | |
| *Pedicularis lanceolata* | * | | |
| Plantaginaceae | | | |
| *Plantago lanceolata* | * | * | |
| Rubiaceae | | | |
| *Galium* sp. | * | * | * |
| Caprifoliaceae | | | |
| *Lonicera tatarica* | * | * | |
| *Viburnum cassinoides* | * | | * |
| *V. dentatum* | | * | |
| *V. lentago* | | * | |
| *Sambucus canadensis* | * | * | * |
| Compositae | | | |
| *Eupatorium maculatum* | * | * | * |
| *E. perfoliatum* | * | * | * |
| *E. rugosum* | * | * | |
| *Solidago* spp. | * | * | * |
| *Aster* spp. | * | * | * |
| *Erigeron annuus* | * | * | |
| *E. philadelphicus* | * | * | |
| *Erigeron* spp. | | | * |
| *Antennaria* sp. | | * | |
| *Anaphalis margaritacea* | | | * |
| *Rudbeckia hirta* | | * | |
| *Achillea millefolium* | | * | * |
| *Chrysanthemum leucanthemum* | * | * | * |
| *Senecio aureus* | | | * |
| *Arctium minus* | * | | |
| *Cirsium arvense* | * | * | * |
| *C. vulgare* | | * | |
| *Taraxacum officinale* | | * | |
| *Hieracium aurantiacum* | | * | |
| *H. pratense* | * | * | * |

Stations 1 and 2 were on extremely sandy soil. From stati
3 to 6 the finer soil fractions remained relatively constant but

e 10. Growth of vegetation (*Cyperus virigatus*) on drained and aerated soils of the margin of Pond 5A at Howland's Island.

nt of soil moisture increased. Stations 7 and 8 were on water-ated but exposed soils where no growth appeared.

The lowest level of production, except for stations 7 and 8, was tion 1 which produced the equivalent of about 2¼ tons of air-naterial per acre. Higher yields were obtained at other stations, ighest being at station 3 which produced approximately three as much as station 1.

## Vegetative Changes in Response to Flooding

In general, much of the vegetation which was present prior flooding died during the following two years on the Swartwood a F.F.A. sites. Of the woody species present at the Swartwood Ma part of the red maple *(Acer rubrum)*, American and slippery e *(Ulmus americana* and *U. fulva)*, alder *(Alnus* sp.) black ash *(Fra nus nigra)*, winterberry *(Ilex verticillata)*, red osier dogwood *(Cor stolonifera)* and meadowsweet *(Spiraea alba)* survived. Of these, meadowsweet seemed to be prospering. None of the herbaceous spe withstood the change in water level.

At the F.F.A. Marsh aspen *(Populus tremuloides)*, red and w oaks *(Quercus rubrum* and *Q. alba)*, water beech *(Carpinus caroli ana)* and thornapple *(Crataegus* sp.) died the first year of flood Willows *(Salix* sp.), winterberry and a few alders survived into second year (Figure 11). Of the herbaceous species present p to flooding, only cattail survived. This species increased, particul in the shallow (6-inch depth) portions of the borrow pit on horizon soils essentially void of organic matter.

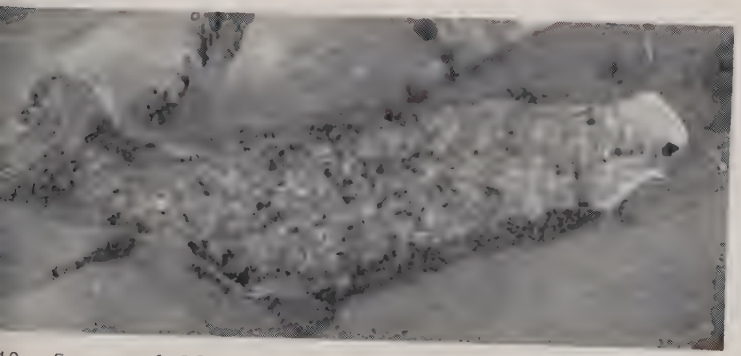
While the loss of rooted vegetation in the two marshes greater than the gain, increases at the Swartwood area were signific and exceeded those for the F.F.A. site. At the former, a blanket duckweeds *(Lemna minor, L. trisulca* and *Wolffia columbiana)* for over more than 50 per cent of the marsh during the first grow season and had increased to fully 75 per cent in 1955 (Figure 1 Beggartick *(Bidens frondosa)* invaded the wet marsh boundary. Fr there to the water edge spikerush was common, while burreed *(Sp ganium curycarpum)* and some cattail appeared from the shore to the 6-inch water-depth contour. No growth of emergents was no beyond the 6-inch contour in either 1954 or 1955.

At the F.F.A. area a sparse growth of spikerush was noted al the unwooded margins of the marsh and, in addition, various f mentous algae occupied about half the flooded area.

## Soil Analyses

The concentrations of essential and non-essential minerals in aquatic environment are dependent, in part, on the composition the soil over which water drains or through which it percolates reach the drainage system. Results of the analyses of drainage a soils are summarized in Table 3.

11. F.F.A. Marsh after being flooded for two years. Note lack of new growth.



12. Swartwood Marsh showing changes in vegetation after being flooded for two years. Note almost complete blanket of duckweeds.

TABLE 3. MEAN CONCENTRATIONS OF MINERALS (IN P.P.M.)*, AMOUNT OF ORGANIC MATTER, AND pH IN DRAINAGE AREA SOILS FOR E OF THREE MARSHES

| Item | Howland's Island | Swartwood Marsh | F.F.A. Marsh |
|---|---|---|---|
| Phosphorus ($P_2O_5$) | 0.80 | 1.05 | 0.70 |
| Nitrogen ($NO_3$) | 2.50 | 3.75 | 2.50 |
| Nitrogen ($NH_3$) | 14.90 | 13.70 | 16.90 |
| Calcium (CaO) | 934.00 | 712.00 | 338.00 |
| Magnesium (MgO) | 116.00 | 55.00 | 50.00 |
| Potassium ($K_2O$) | 41.00 | 29.30 | 48.00 |
| Manganese ($Mn_{++}$) | 33.40 | 19.10 | 33.40 |
| Iron ($Fe_{++}$) | 2.30 | 9.20 | 27.70 |
| Aluminum (Al) | 26.40 | 77.00 | 189.00 |
| Organic matter§ | 2.35 | 2.19 | 2.40 |
| pH | 6.22 | 5.70 | 5.00 |

* Calculated from pounds per acre based on the normally assumed weigh 2,000,000 pounds of air-dry soil in an acre-furrow slice (upper 6 inch
§ Per cent of dry weight.

TABLE 4. MEAN CONCENTRATIONS OF MINERALS (IN P.P.M.)*, AMOUN ORGANIC MATTER, AND pH IN THE SOILS OF THE DRAINAGE A AND OF THE MARSH BASIN BEFORE AND AFTER FLOODING AT SWARTWOOD MARSH

| Item | Drainage area | Marsh basin§ | |
|---|---|---|---|
| | | Before flooding | After floodi |
| Phosphorus ($P_2O_5$) | 1.05 | 3.00 | 2.04 |
| Nitrogen ($NO_3$) | 3.75 | 2.90 | 2.66 |
| Nitrogen ($NH_3$) | 13.70 | 12.20 | 23.20 |
| Calcium (CaO) | 712.00 | 2,121.00 | 1,467.00 |
| Magnesium (MgO) | 55.00 | 191.00 | 163.00 |
| Potassium ($K_2O$) | 29.30 | 23.40 | 20.60 |
| Manganese ($Mn_{++}$) | 19.10 | 31.00 | 31.40 |
| Iron ($Fe_{++}$) | 9.20 | 51.90 | 76.10 |
| Aluminum (Al) | 77.00 | 12.10 | 11.10 |
| Organic matter† | 2.19 | 22.20 | 26.50 |
| pH | 5.70 | 6.08 | 5.98 |

* See footnote to Table 3.
§ Organic fraction of soil.
† Per cent of dry weight.

E 5. MEAN CONCENTRATIONS OF MINERALS (IN P.P.M.)*, AMOUNT OF ORGANIC MATTER, AND pH IN THE SOILS OF THE DRAINAGE AREA AND OF THE MARSH BASIN BEFORE AND AFTER FLOODING AT THE F.F.A. MARSH

| Item | Drainage area | Marsh basin§ | |
|---|---|---|---|
| | | Before flooding | After flooding |
| phorus ($P_2O_5$) | 0.70 | 1.04 | 2.47 |
| gen ($NO_3$) | 2.50 | 2.04 | 1.83 |
| gen ($NH_3$) | 16.90 | 12.00 | 33.70 |
| um ($CaO$) | 338.00 | 1,308.00 | 565.00 |
| nesium ($MgO$) | 50.00 | 142.00 | 93.00 |
| ssium ($K_2O$) | 48.00 | 48.00 | 51.40 |
| ganese ($Mn_{++}$) | 33.40 | 37.00 | 89.60 |
| ($Fe_{++}$) | 27.70 | 54.00 | 395.30 |
| inum (Al) | 189.00 | 117.00 | 75.50 |
| nic matter† | 2.40 | 12.80 | 7.20 |
| | 5.00 | 5.30 | 5.23 |

See footnote to Table 3.
Organic fraction of soil.
Per cent of dry weight.

E 6. MEAN CONCENTRATIONS OF MINERALS (IN P.P.M.)*, AMOUNT OF ORGANIC MATTER, AND pH IN THE SOILS OF THE DRAINAGE AREA AND OF THE MARSH BASIN BEFORE AND AFTER FLOODING AT HOWLAND'S ISLAND

| Item | Drainage area | Marsh basin§ | |
|---|---|---|---|
| | | Before flooding† | After flooding† |
| phorus ($P_2O_5$) | 0.80 | 0.75 | 1.95 |
| gen ($NO_3$) | 2.50 | 5.30 | 7.15 |
| gen ($NH_3$) | 14.90 | 11.60 | 53.10 |
| um ($CaO$) | 934.00 | 2,452.00 | 2,408.00 |
| esium ($MgO$) | 116.00 | 273.00 | 279.50 |
| sium ($K_2O$) | 41.00 | 39.00 | 31.60 |
| ganese ($Mn_{++}$) | 33.40 | 35.00 | 105.00 |
| ($Fe_{++}$) | 2.30 | 52.00 | 294.00 |
| inum (Al) | 26.40 | 21.00 | 21.00 |
| nic matter‡ | 2.35 | 9.10 | 14.50 |
| | 6.22 | 6.15 | 6.89 |

ee footnote to Table 3.
Organic fraction of soil.
ond 5A, flooded continuously beginning in 1934; data for conditions before
ooding obtained from contiguous area (see text).
er cent of dry weight.

Table 7. Mean Concentrations of Minerals (in p.p.m.)*, Amoun Organic Matter, and pH in Submerged and in Drained Aerated Soils of Pond 5A at Howland's Island

| Item | Submerged soils | | Drained and aerated s | |
|---|---|---|---|---|
| | Organic layer | Mineral layer | Organic layer | Miner layer |
| Phosphorus ($P_2O_5$)..... | 1.95 | 0.63 | 0.68 | 0. |
| Nitrogen...($NO_3$)..... | 7.15 | 7.94 | 5.40 | 5. |
| Nitrogen...($NH_3$)..... | 53.10 | 43.90 | 9.50 | 15. |
| Calcium....(CaO)..... | 2,408.00 | 1,547.00 | 1,598.00 | 1,247 |
| Magnesium.(MgO).... | 279.50 | 287.50 | 192.00 | 209. |
| Potassium..($K_2O$)..... | 31.60 | 20.40 | 41.50 | 30. |
| Manganese.($Mn_{++}$).... | 105.00 | 108.00 | 20.60 | 40. |
| Iron.....($Fe_{++}$).... | 294.00 | 292.00 | 21.60 | 18. |
| Aluminum..(Al)..... | 21.00 | 29.00 | 19.00 | 17. |
| Organic matter§..... | 14.50 | 1.70 | 4.40 | 0. |
| pH..... | 6.89 | 7.38 | 6.05 | 6. |

* See footnote to Table 3.
§ Per cent of dry weight.

Table 8. Mean Concentrations of Minerals (in p.p.m.)*, Amoun Organic Matter, and pH in Surface Mud of Pond 18 Howland's Island at Intervals after Being Drained in F Fall§

| Item | Date sampled | | | |
|---|---|---|---|---|
| | November 19, 1953 | December 18, 1953 | January 1, 1954 | January 1954 |
| Phosphorus.($P_2O_5$)... | 7.2 | 5.6 | 4.5 | 3. |
| Nitrogen...($NO_3$)... | 9.8 | 7.1 | 7.3 | 8. |
| Nitrogen...($NH_3$)... | 70 | 67 | 62 | 56. |
| Calcium....(CaO)... | 3,104 | 3,192 | 3,575 | 3,058 |
| Magnesium.(MgO).. | 244 | 275 | 258 | 240 |
| Potassium..($K_2O$)... | 31.5 | 21.5 | 23.7 | 18. |
| Manganese.($Mn_{++}$).. | 106 | 121 | 84 | 96 |
| Iron.....($Fe_{++}$)... | 365 | 253 | 198 | 266 |
| Aluminum..(Al)..... | 62 | 39 | 28 | 32 |
| Organic matter†.... | 23.8 | 16.2 | 18.4 | 14. |
| pH..... | 6.75 | 6.62 | 6.77 | 6. |

* See footnote to Table 3.
§ Pond drained on November 18, 1953.
† Per cent of dry weight.

The relationships between soils of the drainage area and those
ie marsh basin before and after flooding are given in Tables 4, 5
6. The influence of drainage and soil aeration on the concentra-
of soil constituents is shown in Table 7.
The foregoing data apply to conditions that may obtain follow-
summer drainage and the growth of a crop. In Table 8 changes
oil chemistry following drainage just prior to ice formation are
ated.
general, the direction of change in the concentrations of soluble
ent salts for each situation noted in the foregoing tables might
been predicted. However, certain deviations are understandable
after a more detailed description of site characteristics prior to
ing, while some of the changes cannot be explained by the data
able. Before discussing these data, it seems advisable to present
ges which were noted in the physical and chemical properties
e water of the marshes studied as they relate to the concentration
luble salts essential for the growth of rooted aquatics in the marsh

### sical and Chemical Properties of the Water

In evaluating the data recorded for the physical and chemical
erties of the water, one must bear in mind that the bodies of
r under consideration (Swartwood and F.F.A. Marshes) were
cted from wind action by both topography and vegetation of
drainage area and by woody vegetation in the marsh basin proper.
sheltering influence, as well as reduction of solar radiation by
ng, was more pronounced in 1954 than in 1955 (Figures 1, 2,
id 12). As may be noted in these illustrations, the reduction in
ge between years could have resulted in significant changes in
ceipt of total energy by the water masses.
Mean summer air temperatures were quite different during the
vears of study. For the months of June through September in
they were 6.6°F. below the long-term mean, while for the same
d in 1955 they were 5.2°F. above that level.

Thermal Stratification Temperature gradients were deter-
l by noting water temperatures at the time water samples were
ied for dissolved oxygen determinations, and, in addition, at the
wood Marsh by a triple recording thermograph. This equipment
calibrated at frequent intervals against Thomas maximum-

minimum thermometers each with a guaranteed accuracy of less t 1° F. The record from this thermograph, for one day in the sum of 1955, is shown in Figure 13.

The continuity of the thermograph records made possible a f appreciation of chemical and biochemical events that occurred in marshes. Of particular importance was the strength of the ther stratification as illustrated in Table 9.

Table 9. Water Temperature Gradients Recorded for the Same tion at the Swartwood Marsh on Single Days in Jul 1954 and 1955

| Depth | Temperature in degrees Fahrenhei | |
|---|---|---|
| | 1954 | 1955 |
| Surface | 80 | 90 |
| 1-foot | 68 | 81 |
| Bottom§ | 60 | 68 |

* Average for 24-hour period.
§ Because the water level maintained at the dam differed for the two y the bottom depth at this station was 2 feet 10 inches in 1954 and 3 7 inches in 1955.

The constancy of bottom temperatures throughout the sum season and the persistence of the water temperature at 1 foot to rel below that at the surface (1 inch) are of primary importance. N specifically, such evidence of summer stagnation of bottom wa which usually cover muds rich in organic matter, points to an e onset of anaerobic conditions and to their continuance throug much of the growing season. The relationship between the gro of rooted aquatic plants and changes which develop under anaer conditions will be referred to frequently, both directly and indire throughout the remainder of this paper.

The thermograph records represent continuous temperature for only a single location at one marsh. For a more adequate as ment of water temperatures for the two marshes, the mean for water depth on each day records were taken was calculated from data for all the sampling stations (Figures 5 and 6). These m are plotted in Figures 14 and 15.

The data from the F.F.A. Marsh are weakened by lack of tinuity, i.e., no thermograph records were obtained. As the s

Figure 13. Thermograph record for one station at the Swartwood Marsh on June 27, 1955.

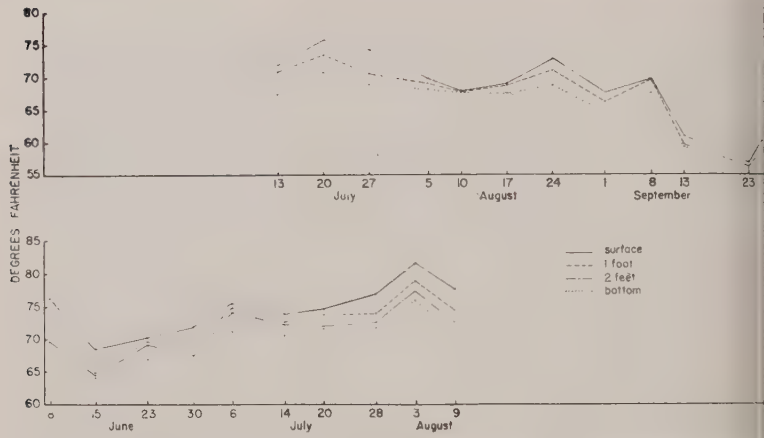



Figure 14. Mean water temperatures recorded at the Swartwood Mars 1954 (above) and 1955 (below).

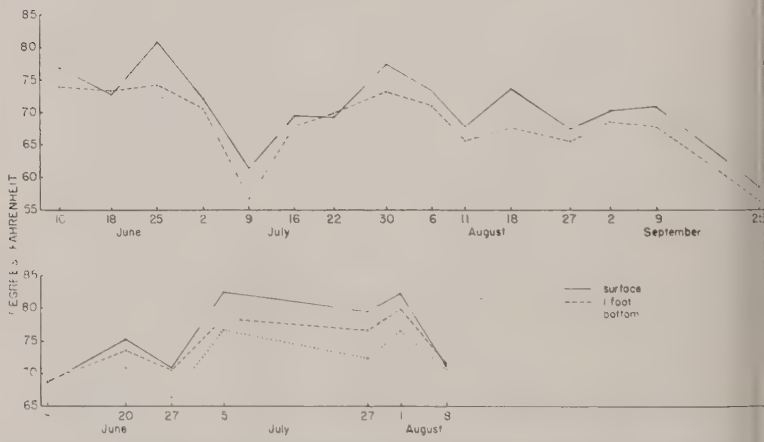



Figure 15. Mean water temperatures recorded at the F.F.A. Marsh in (above) and 1955 (below).

general temperature pattern was noted at both sites, it may be assu that diel changes were of insufficient magnitude to produce isothe conditions at any time during the periods represented in Figure

At the F.F.A. site, as at the Swartwood Marsh, reductio foliage from 1954 to 1955 probably contributed to the warmer w temperatures observed.

Sharp rises in water temperature on October 1 and 2, 1954 associated with an abnormally warm period of 7 days from Septe

through October 4. Mean air temperatures were 11.43° F. higher n the long-term mean for these dates. (Data from the Cornell ather Station, about 11 air line miles from the Swartwood Marsh.) ter temperatures became isothermal during the week of October 1954.

It will be noted that the mean temperatures calculated did not respond to those recorded by the thermograph. The thermograph shaded by foliage and housing equipment, whereas the sampling ions were exposed to more direct radiation, particularly in 1955.

It is not to be inferred that we have concluded that these thermal dients were solely a result of protection from wind action. Similar terns were noted at other shallow-water areas where neither topogphy nor vegetation would have prevented normal air movement. An n pond at Delmar (N. Y.) exhibited the following on July 17, 4: surface, 80.8°F.; 1 foot, 79.9°F.; 2 feet, 76.1°F., 3 feet, 74.3°F.; eet 10 inches, 73.3°F. Comparable gradients were noted at Oak hard Marsh, an area of several hundred acres, and at the smaller kcock Marsh, on July 10 and 11, 1954. Both are in western v York. Barickol and Campbell (1952) and Brundin (1949) noted mal stratification in shallow water areas although they were conrably deeper than those under observation during this study.

Winter water temperatures were noted for Pond 14 at Howland's nd. Temperature patterns were normal, i.e., temperatures through- were at or near 39.2°F. (4°C.), from January 16 through Febru- 13, 1954. On February 15, a general thaw prevailed in central v York, and water temperatures on February 20 increased toward bottom and were above that of maximum density, viz: surface, 9°F.; 1 foot, 39.0°F.; 2 feet, 40.5°F.; 3 feet, 41.0°F.; bottom rious depths), 41.5°F. It was also noted that, for a given depth, were progressively greater from the outlet end of the pond toward inlet. In other words, the warmer water flowing into the pond led to push under the colder, more dense water already in it. s was especially evident at sampling stations situated over the inal flowage channel. Thus a typical density-flow pattern was ent, the warmer replacement or melt water being concentrated in a relatively narrow area within the impoundment which resented the greatest depth in cross-section.

Chemical Stratification Thermal stratification should result nd be augmented by chemical layering. Thus, it is of more than ing interest that the concentration of dissolved oxygen did vary

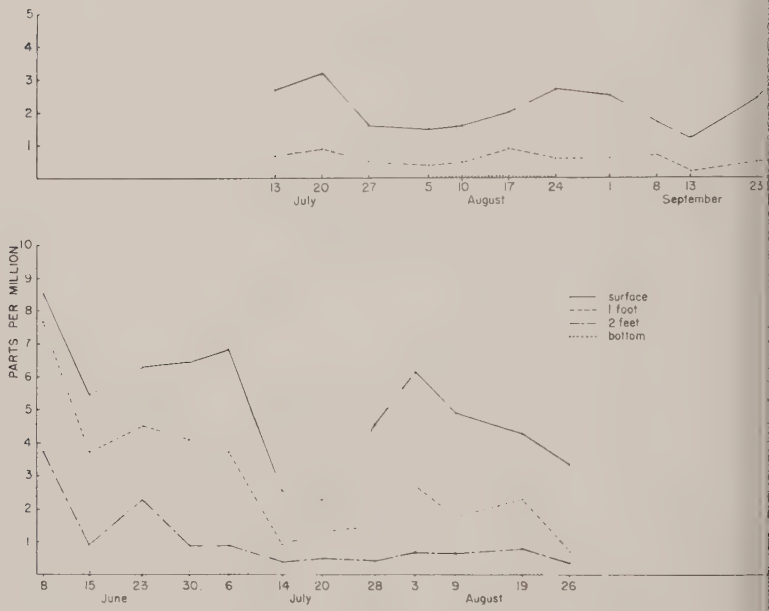



Figure 16. Concentrations of dissolved oxygen recorded at the Swart Marsh in 1954 (above) and 1955 (below).

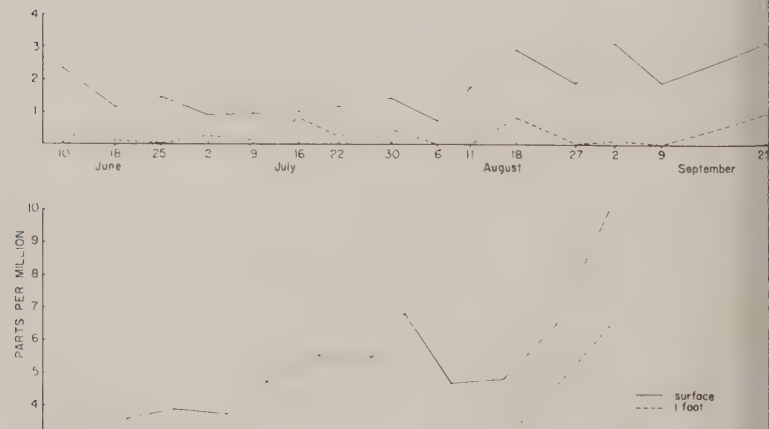



Figure 17. Concentrations of dissolved oxygen recorded at the F.F.A. M in 1954 (above) and 1955 (below).

elation to water depth (Figures 16 and 17). Changes in the dis-ed oxygen content of marsh waters between years will be discussed r.

The amount of dissolved oxygen in a shallow-water environment ng the period of ice cover was recorded for Pond 14 at Howland's nd (Table 10). Oxygen depletion at this site was correlated with

LE 10. Concentrations of Dissolved Oxygen (in p.p.m.) at Different Depths for Eight Stations in Pond 14 at Howland's Island Immediately Before and During a Thaw

| epth | Station | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Before thaw (February 13, 1954) | | | | | | | | |
| ice..... | 0.86 | 1.18 | 1.19 | 1.39 | 2.56 | 2.34 | 2.92 | 11.39 |
| t..... | 0.50 | 0.80 | 0.71 | .. | 3.16 | 2.07 | 2.57 | 11.01 |
| t..... | 0.50 | 1.09 | 1.55 | .. | 2.17 | 1.94 | 5.70 | .. |
| t..... | 0.46 | 0.50 | 1.12 | .. | .. | .. | 4.02 | .. |
| om.... | 0.00 | 0.27 | 0.65 | 0.01 | 1.96 | 1.41 | 3.16 | 6.09 |
| During thaw (February 20, 1954) | | | | | | | | |
| ice..... | 5.34 | 4.51 | 7.07 | 6.16 | 10.40 | 8.26 | 7.85 | 12.59 |
| t..... | 2.23 | 2.17 | 2.85 | 3.24 | 10.54 | 5.35 | 5.74 | 10.46 |
| ..... | 0.04 | 1.55 | 2.05 | 6.79 | 11.88 | 6.34 | 2.73 | .. |
| t..... | 0.15 | 1.34 | 4.77 | .. | .. | .. | 9.00 | .. |
| om.... | 0.00 | 1.91 | 5.52 | 7.27 | 11.13 | 7.17 | 9.10 | 8.73 |

length of time between thaws. Following thaws oxygen concen-ons were highest near the inlet (Station 8) and diminished at evels of sampling toward the outlet (Station 1), except for Station ated over the flowage channel.

Several other marshes of different types sampled during the stigation showed strong oxygen stratification during the summer. general situation which prevailed is indicated by dissolved oxygen from an open pond at Delmar (N. Y.) on July 14, 1954. They as follows: surface, 12.65 p.p.m.; 1 foot, 13.17 p.p.m.; 2 feet, p.p.m.; 3 feet, 3.31 p.p.m.; and bottom (3 feet 10 inches), p.p.m.

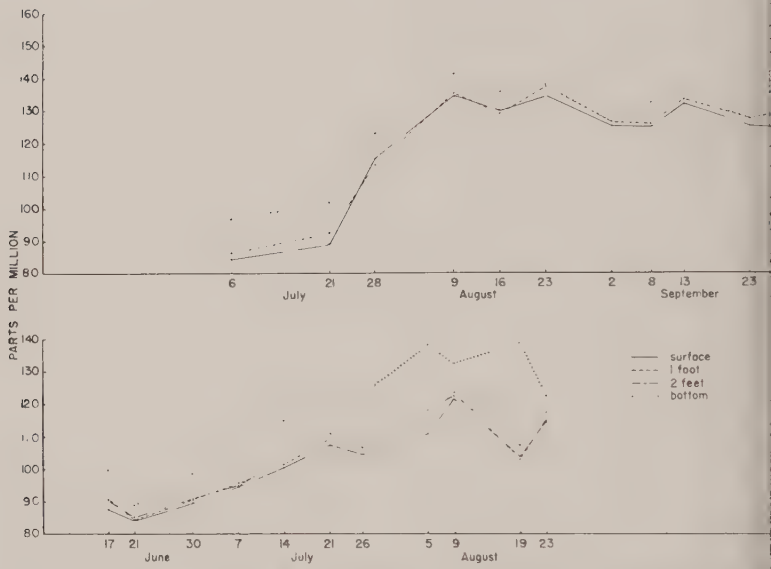



Figure 18. Mean levels of total alkalinity recorded at the Swartwood M in 1954 (above) and 1955 (below), exclusive of Stations 2 a to the 1-foot level in 1954.

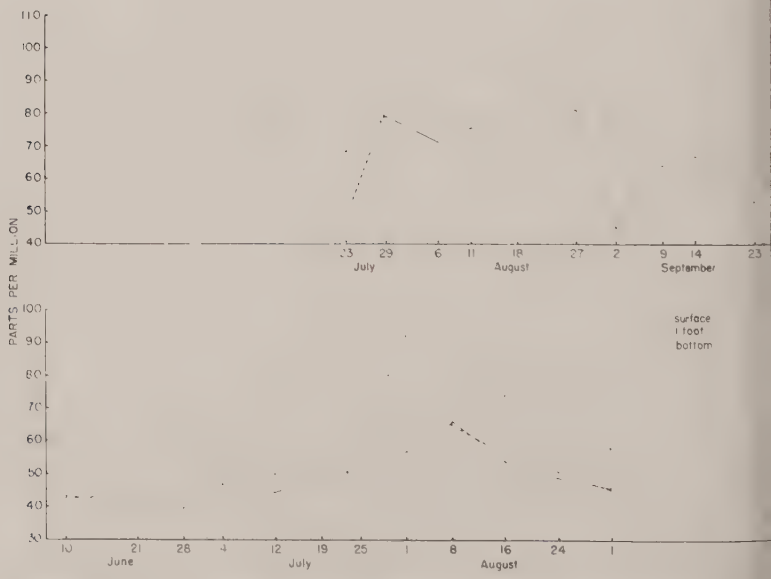


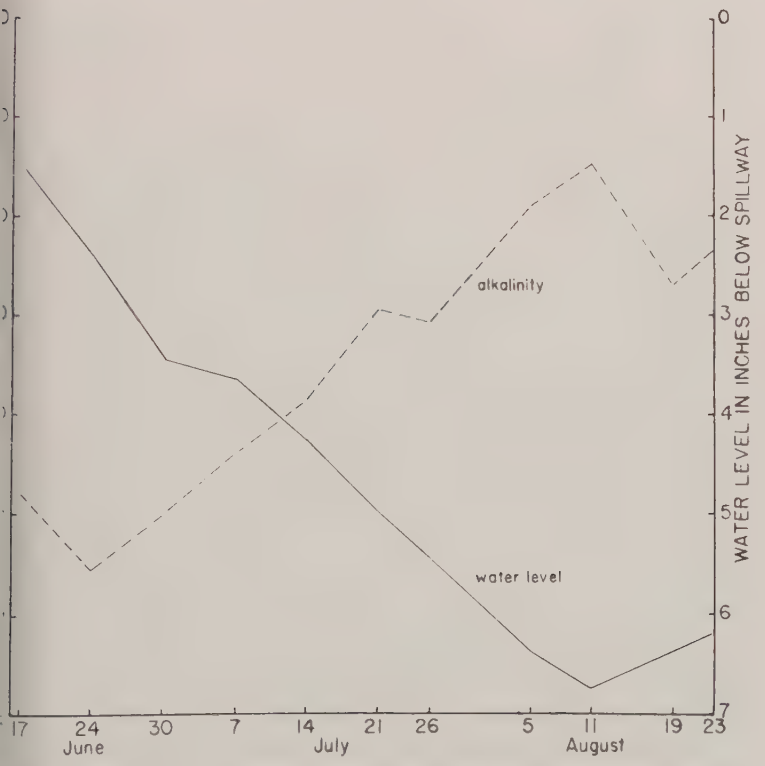

Figure 19. Mean levels of total alkalinity recorded at the F.F.A. Mars 1954 (above) and 1955 (below).

TOTAL ALKALINITY The suggested tendency for the amount dissolved oxygen to decrease with depth should be reflected in nges in concentration of total alkalinity. Data summarizing alkalin- elationships are given in Figures 18 and 19.

These graphs show there was a tendency for total alkalinity to ease at the Swartwood Marsh and to decrease at the F.F.A. Marsh n 1954 to 1955.

FLUCTUATIONS IN WATER LEVEL Intraseasonal variations in r levels may result from evaporation, transpiration, lateral capil- y, percolation, drainage, and precipitation.

In 1954 the water level at the Swartwood Marsh was lowered 9 es by regulating the height of the mechanical spillway. At the A. Marsh, also in 1954, water loss through leakage accounted




e 20. Relationship between mean total alkalinity and water level at the Swartwood Marsh in 1955.

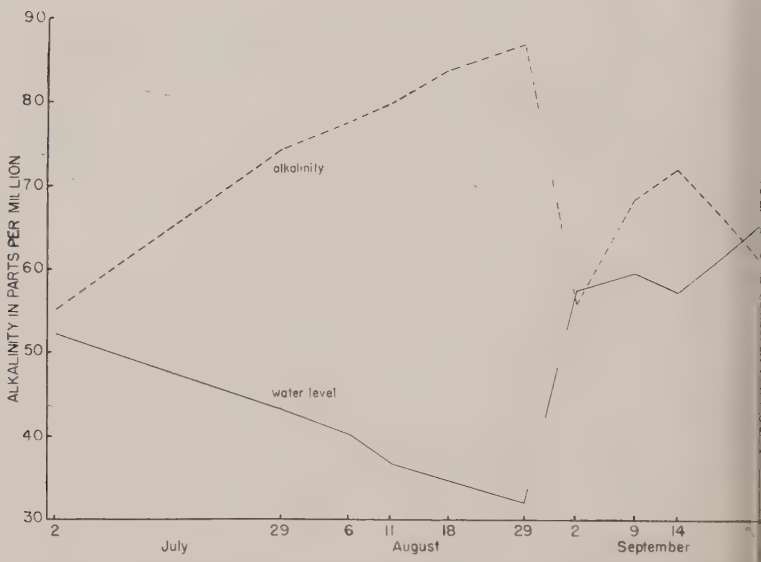



Figure 21. Relationship between mean total alkalinity and water leve the F.F.A. Marsh in 1954.

for an unknown drop in the water level, while in 1955 water los these two sites could be charged entirely to natural forces.

The inverse relationship between total alkalinity and cha in water level is of interest (Figures 20 and 21). This relation was observed in both marshes in 1954 and 1955, and possible ca for these opposing patterns will be treated in the discussion of w levels.

## DISCUSSION

In considering the data presented it is clearly impossible to div one aspect from others because of the interdependence of their r tionships. For ease in understanding, however, each feature wil considered independently and then related, when possible, to the w as this broader concept applies to marsh management.

Botanical surveys of basins before flooding furnished data w could not be related to soil fertility, to the concentration of nutri or to soil structure or texture. The presence of water plantain *(Al planatago-aquatica)* at the Swartwood Marsh only may be explai It grew in a small area of open water which persisted well into summer of 1953. The elevation of the F.F.A. area may be relate the presence of ground pine *(Lycopodium complanatum)* as H (1924) indicated that many species of this genus occur chiefl

ıer elevations. The genus *Vaccinum* was noted only at the Swart-d and F.F.A. sites. Its absence from Howland's Island may be endent on the more alkaline soils of this area. The greatest variety pecies occurred on the largest area, Swartwood Marsh. In addi-, many species, not recorded for a specific basin, were seen on lands he immediate vicinity. For central New York conditions, plant cators, which would reveal site characteristics prior to flooding productive capacity following submergence, are not evident in the a acquired.

Surveys of plant communities associated with man-made shallow-er environments which have been flooded continuously for rela-ly long periods (20 years or more) suggest that plant complexes ch develop may not be highly productive of food and cover for dife. The end results and, possibly, the course of events which lead to relatively nonproductive wildlife marshes will be con-red more fully when marsh management practices are evaluated. Following initial drainage of marshes, after several consecutive s of submergence, plant growth may be exceptionally luxuriant gures 10 and 22). It is axiomatic that relatively great amounts

e 22. Growth of vegetation *(Polygonum lapathifolium)* on drained and aerated soils at Pond 9 on Howland's Island.

of essential nutrients would be required to produce such grov
The source of these essentials is of special interest.

Soil aeration, following drainage, would tend to result in
accelerated rate of decomposition of accumulated organic mater
Such breakdown should release a wealth of nutrients, part of wh
could promote the growth of macroscopic plants. This statement
seem contradictory because of the wide nitrogen-carbon ratio of
soils. A pronounced increase in organisms of decomposition wo
be expected with soil aeration and, further, it would seem logica
assume that these organisms, supplied with an almost limitless sou
of energy, would acquire a large proportion of the nutrients releas
to the detriment of higher plants. Yet one of the anomalous feat
of organic soils is that they support vigorous nitrification (Lyon
Buckman, 1949).

Comparison of the data in Table 7 suggests that the loss of org
matter following drainage was approximately 70 per cent in 63
This decomposition, with concurrent release of mineral nutri
could have resulted in the heavy yields observed. However, the
of accumulation of this organic deposit was 20 years. It is thus evi
that annual drainage could not effect a comparable release of esse
salts from the same source. Excessive accumulations of organic
ter, *per se,* seem to have no special attribute for the betterment
shallow-water environments, save as this material may conserve es
tials for plant growth. On the contrary, organic accumulations w
they exceed that for mineral soils (about 4 per cent) may, indire
be decidedly harmful in shallow, aquatic habitats. Because the r
lation of organic matter has a direct bearing on the managemen
artificial marshes, it will be discussed when this problem is conside

Vegetative changes in response to short-term flooding have
covered, in the main, by direct observation. Those associated
long-term submergence may be partially explained in terms of phy
modification of the submerged soils.

As previously noted, sampling stations 1 and 2 on the ma
of Pond 5A at Howland's Island were on sandy soil. This shal
water area has relatively steep margins. Wave action had so
and carried from its perifery most of the finer soils leaving a relati
sterile growth medium not suited to produce vegetation in amo
that would be especially attractive to wildlife.

The chemistry of submerged soils may be related to the intr
concentration of essential elements in soils of a drainage area
to site characteristics prior to flooding.

In considering the quality of drainage area soils (Table 3), it d be noted that the Ontario series at Howland's Island were drained; the Volusia clays at the F.F.A. Marsh were, in part, y drained; and the lacustrine soils surrounding the Swartwood h were intermediate between the two.

The amount of soluble iron in the soils of these drainage areas ars to be related to their relative wetness, or more directly to the sity of reducing conditions which would obtain, generally, under r-logged conditions.

Differences in aluminum content may be correlated with the int of clay present. In this respect the soil at Howland's Island low; that at the F.F.A. Marsh, high; and that at the Swartwood h was again intermediate between the two. Aluminum is not tial to plant growth. With a low pH this metal may become mely toxic to certain agricultural crops (Hartwell and Pember, ). While this relationship has not been established for aquatic s, it would probably apply.

Of special interest are the relative amounts of calcium and mag- m in the soils surrounding the marsh basins. Here again, wide rences in concentration may be noted, with the most favorable tity in the soils at Howland's Island, the least at the F.F.A. Marsh, an intermediate amount at the Swartwood Marsh.

The concentration of calcium and magnesium is reflected in pH, ugh the clay content of the soil together with its greater abun- e of aluminum could also influence this factor. Maintenance desirable pH in submerged soils is a problem related to the regu- n of the environment. A consideration of this phenomenon, her with some factors which may influence it, will be included r marsh management.

For the remaining items in Table 3 (phosphorus, nitrate and onia nitrogen, potassium, manganese, and organic matter), dif- ces in amounts were not great except for manganese. No explana- is evident as to why the Swartwood area soils contained only t half as much of this element as those surrounding the other two nes.

Marsh basin soils before and after they are flooded generally are richly supplied with essential nutrients than are contiguous nd soils. This is evident in data contained in Tables 4, 5 and With respect to the data in Table 6, soils from the marsh-basin flooding represented those that had been submerged for about ars. Thus, these data are not entirely comparable with those

of Tables 4 and 5 and will be considered independently. Bartholon (1931) and Ponnamperuma (1955) concluded that the solubility phosphorus was increased by soil submergence, and Mortimer (19 noted an increase of over 100 per cent following flooding of soil the development of anaerobic conditions. Tisdale and Nelson (19 have suggested that phosphorus availability is at a maximum, agricultural soils, at a pH range of 5.5 to 7.0. Below pH 5.5 element may be precipitated in insoluble iron and aluminum co pounds, and above pH 7.0, in those of calcium and magnesium. Un anaerobic conditions together with high concentrations of car dioxide supplied by the breakdown of organic matter, iron, calci and magnesium would go into solution as bicarbonates thus releas phosphorus for assimilation by living tissue.

At both the F.F.A. and Swartwood Marshes, the soluble ph phorus content of the marsh basin soils was notably greater than t in the soils of the drainage area. After flooding and the establishm of reducing conditions, it decreased at the Swartwood Marsh increased at the F.F.A. Marsh. At the former area an intense blo of phytoplankton and zooplankton was observed—a condition noted at the latter. The relative abundance of these organisms betw areas could not be determined precisely because of their discontinu distribution. One can conclude safely, however, that the Swartw Marsh supported much more than did the F.F.A. Marsh. Furt it is distinctly possible that the reduction in available phosphoru the Swartwood site following flooding, was related directly to difference.

The general reduction in nitrate nitrogen following the deve ment of anaerobic conditions in the basin soils, both before and a flooding, could have been predicated. The lesser amount of ammo nitrogen in the unflooded but partially water-logged basin soils relation to the higher concentration in the drainage area soils, have been related to the luxuriant growth of vegetation in the bas Alternate explanations for these differences are not evident. Foll ing flooding, however, the increase in ammonia nitrogen would h been expected.

Differences in the amount of available calcium and magnes between the drainage area and the unflooded basin soils are ma These differences tend to emphasize the results of lysimeter tests wh indicate that the movement of these two elements from drainage a can be great. Further, these data point clearly to the tendency these two base ions to accumulate in basin soils.

Following flooding, a large proportion of the calcium was removed
n the basin soils of both the organic and inorganic layers. At
Swartwood Marsh this amounted to about 31 per cent for the
nic layer and 33 per cent for the mineral layer. At the F.F.A.
the proportions were about 57 per cent and 35 per cent, respec-
y. These changes may be attributed to three phenomena.

Initially, large amounts of calcium would be converted to a
rbonate, and as such, would be subject to transport by both lateral
vertical movement of water from the impoundment. This frac-
of the total would largely be lost to the marsh environment.
vever, bicarbonate would also be dispersed through the water
aining in the marsh and would (in part) remain in solution and
part) be incorporated into living tissue. These portions would be
ined in the environment providing the marsh was not drained.

What applies to calcium in this respect would apply to magne-
, but with the latter its accumulation in the lower, mineral portion
he soil profile emphasizes the influence of downward movement.

The solubility of potassium should increase after a soil is flooded.
following may illustrate the change that takes place under reduc-
conditions at the mud-water interface:

$$2KAlSi_3O_8 + 2H_2O + CO_2 \longrightarrow H_4Al_2Si_2O_9 + 4SiO_2 + K_2CO_3$$

of this soluble potassium would be adsorbed on clay and organic
ids, part would be dispersed through the water and soil solution,
would be lost by lateral and vertical water movement, and the
ainder would be absorbed by living tissue. Potassium, like certain
r nutrients, may be absorbed in luxury amounts.

In considering the data in Tables 4 and 5 which relate to this
ent, it is evident that soils at the Swartwood Marsh gave up a
tantial amount. Because of the great abundance of plankton plus
large crop of duckweeds, it seems reasonable to assume that much
ne decrease in potassium content of the soils resulted from its use
nose organisms.

At the F.F.A. Marsh where the amount of plankton was decidedly
the data (Table 5) indicate a low order of increase in soluble
ssium.

Manganese, while essential for the growth of rooted aquatic
ts, is required in extremely small amounts. It may be present in
nomic soils in divalent, trivalent and tetravalent forms, with the
r essentially inert. After flooding and the development of reduc-
conditions, the divalent or manganous form is dominant in marsh

soils. At the Swartwood area the concentration of soluble manga increased only a little after flooding whereas at the F.F.A. site increase was of major proportions. For New York conditions probable that marsh soils would contain rather large amounts of element in solution shortly (6 months) after flooding.

The behavior of iron in submerged soils is similar, in r respects, to that of manganese. While both ferric and ferrous f may be absorbed by plants, it is the latter which is biologically ac This element is required in minor volume by agricultural crop general, but Ponnamperuma *(op. cit.)* has shown that substa amounts are required for the prosperous growth of rice. It is tinctly possible that desirable rooted aquatic plants would parallel in this respect.

Under submerged soil conditions and in the presence of a st reducing agent (organic matter in marsh soils), with dissolved ox not more than 0.5 p.p.m. and relatively high concentrations of ca dioxide, iron goes into solution. The reasons for the erratic beha of soluble iron in the soils of the Swartwood Marsh following floo are not evident. At the F.F.A. site, on the other hand, the inc in soluble iron followed the expected pattern.

No explanation can be offered for the behavior of aluminum flooding at either site.

The increase in the organic content of submerged soils well known and understood that specific comment is not neces

The differences in pH between the drainage area soils and of the unflooded basin may be related to the markedly greater amo of calcium and magnesium in the latter. Conversely, reduction in after flooding may be correlated with removal of calcium and ma sium from the soil solution. The generally higher pH in the mi portion of the soil profile, compared with that in the organic l appears to be a function of cation adsorption capacity which incr sharply with an increase in organic matter.

Changes in soil chemistry associated with relatively long pe of flooding are as important, if not more so, to marsh manage as are initial changes. For an estimate of conditions which result 20 years of continuous submergence, data in Table 6 may be sidered.

In general the same pattern of changes is to be noted as observed in Tables 4 and 5. However, it may be seen that little ch was evident in the calcium content of the soils before and after f ing. This again suggests that calcium is received by the flooded-

from the drainage area in rather large amounts. Long-term ıergence may also result in rather pronounced increases in soil providing the loss of base ions is not great. Dennett (1932), (1932), Reed and Sturges (1937) and Mortimer *(op. cit.)*, ng others, have demonstrated an increase in soil pH after flooding defined reasons for it.

Mortimer concluded ". . . the fact that vertical chemical stratifica- is maintained in the water column suggests that the main agents roduction or depletion of dissolved substances are located at the r boundary of the column, at the mud surface." It is evident, fore, that much of the total solutes within the water mass of hes has as its origin the submerged soils.

Data obtained from the analyses of soil samples representing itions following flooding suggest that substantial amounts of ıtial nutrient salts were lost from the bottom muds, presumably oing into solution above the mud-water interface. Among these be cited calcium, magnesium, phosphorus, and potassium. In cases, except for the portion removed by vertical and horizontal r movement, the loss would be represented by the total amount ıe water. This, in turn, would be that in solution, in suspension, rporated in living tissue, and adsorbed on colloids dispersed ughout the water colum. Thus, rapid removal of water (i.e., ıage) would of necessity carry with it much of its total load of ent salts.

When drainage took place in summer, the magnitude of change sential elements was much greater than when drainage occurred prior to ice formation. In order to appreciate more fully these rences, a discussion of the characteristics of the water of marshes licated.

Changes in submerged soils are related in a direct way to water erature and stratification within the water column, to the con- ation of dissolved oxygen and to the rate of evolution of carbon de.

Temperature gradients, as observed, indicate that summer strati- on in the shallow waters of marshes is real. The strength of this fication is indicated by the fact that winds of hurricane "Connie" August 13, 1955) did not produce isothermal conditions at the twood Marsh, the only site for which such data are available.

Thermal stratification and hence a water density gradient which nts mixing of the water column should be present before dis-

solved oxygen concentrations decrease with depth. At the sites u observation, oxygen stratification was evident.

The interrelationships between dissolved oxygen and other so in the water column are of special interest. When oxygen con trations are high, many of the essentials for the growth of re aquatic plants will be precipitated. On the other hand, when amount of dissolved oxygen is low and carbon dioxide concentra are high—a condition which may exist except for relatively periods during the spring and fall—a much richer supply of nut salts is available.

In this connection, the solubility of the components which toge influence total alkalinity of marsh waters may be considered. T alkalinity is usually designated as the sum of hydroxides, carbon and bicarbonates. As no phenolphthalein alkalinity (hydroxides carbonates) was noted during this study, total alkalinity represe bicarbonates solely. Since calcium and magnesium in the subme soils were high in abundance in relation to other bases, it fo that total alkalinity represented largely the presence of calcium magnesium bicarbonates.

Calcium is sparingly soluble in pure water (0.0014 gram per milliliters at 25°C.), yet it is readily soluble in carbonic acid. H concentrations in amounts above that for distilled water are re to the accumulation of carbon dioxide. The salient features o carbon dioxide cycle have been treated fully and with unusual cl by Ruttner (1953). It would be redundant to restate his conclu as no essential differences, except those of degree, were noted bet his data for lakes and those of this study for marshes.

Diffusion rates are of too low an order to interfere seriously the gradient in solutes as recorded. Further, throughout the there was no evidence that eddy diffusion disrupted biochem stratification even though wind action caused marked shifting of floating vegetation, *Lemna* in particular.

Before leaving the subject of carbon dioxide, it is of interest value to note the apparent relationship between the concentrati total alkalinity and fluctuations in water level (Figures 20 and While data are summarized for one marsh in 1954 and the oth 1955, parallel relationships were noted at both during these y The unusually strong inverse correlation between these two ponents of the environment is thought to have been fortuitous. C depicting initial observations of total alkalinity rise abruptly ea the summer season for all depths of sampling. A general inc

tal alkalinity may be noted with the advance of the warm season
e F.A. Marsh, while shallow fluctuations occurred at the Swart-
Marsh where alkalinity remained at a generally high level.
r levels, on the other hand, decreased more uniformly. Had
elationships between total alkalinity and decreasing water depth
related solely to a concentrating effect upon the calcium bicar-
te, correlation between them should be linear. If, however, this
onship can be attributed to the rate of evolution of carbon
de, the correlation should be curvilinear. An exploration of
possibilities may be informative.

As bicarbonate concentrations increase, the carbon dioxide must
ase more rapidly; that is, the concentration of carbon dioxide
red to maintain calcium bicarbonate in solution must increase
more rapidly than does the bicarbonate. If additional amounts
lcium are to be brought into solution as a bicarbonate, carbon
de in excess of equilibrium concentrations is required (aggressive
n dioxide). It seems pertinent to speculate on the possible source
d reasons for changes in the concentration of this gas.

Carbon dioxide evolution should be related to the temperature at
ud-water interface, to the amount of decomposable organic mat-
nd to the ease with which this material may be broken down. As
m temperatures rise during early summer and the organic
ial readily susceptible to bacterial action is attacked, the con-
ation of carbon dioxide should rise rapidly. With a gradual
ing of bottom temperatures in late summer and early fall, the
of decomposition should decrease and a corresponding drop
d occur in carbon dioxide and hence in bicarbonates, even
h the water level were to continue downward. If this satisfies
equirements for changes in the concentration of carbon dioxide,
nence in the concentrations of bicarbonates, total alkalinity is
elated wholly to water volume as Figures 20 and 21 would sug-
Rather, the relationship is curvilinear and thus related more
ly to the sum of factors controlling carbon dioxide production,
ing adequate amounts of calcium and magnesium (Figure 23).
it cannot be denied that some concentration of total alkalinity
occur with evapo-transpiration water loss, this influence appears
masked by that of carbon dioxide.

The highest values noted for total alkalinity in Figure 23 were
ed from bottom samples that were turbid. Such samples were
tently higher in total alkalinity than were samples free from
n debris. This apparent curvilinear behavior of total alkalinity

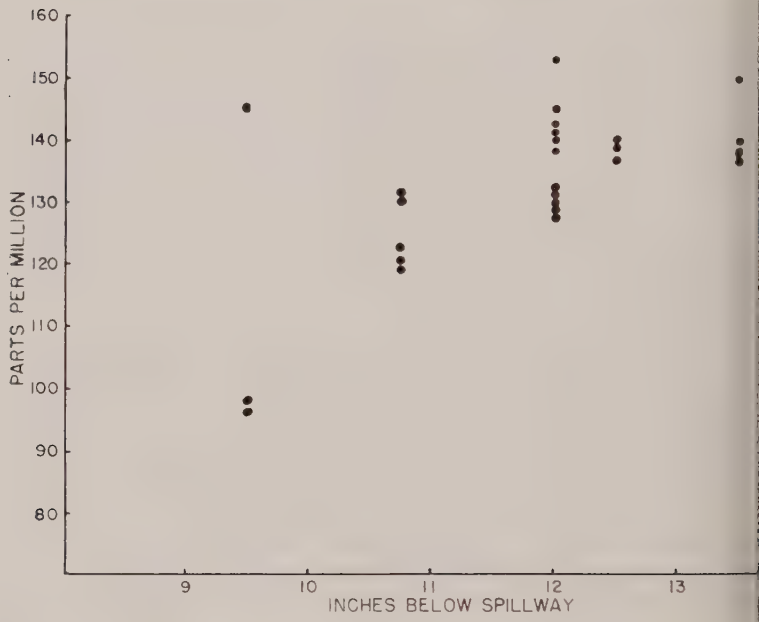



Figure 23. Relationship between total alkalinity ($CaCO_3$ in p.p.m.) water level at the Swartwood Marsh.

concentrations is indicated more clearly when these aberrant va are omitted.

The evolution of carbon dioxide at the mud-water inter should be high as a result of cellulose fermentation. With the stratification this gas would accumulate in aggressive amount this depth. Coupled with this is the fact that photosynthesizing p would remove half-bound carbon dioxide from the bicarbonate, re ing in the precipitation of calcium carbonate from the zone of a photosynthesis. On settling, the monocarbonate would be met by aggressive carbon dioxide. Thus, at the mud-water interface de high concentrations of calcium bicarbonate should be encounte particularly when the muds are disturbed at the time of sample lection. This may serve to explain the increase in total alkali with depth, and the apparently aberrant concentrations noted in tu samples.

Further reference to the carbon dioxide cycle is necessar order to appreciate more fully the relationship between this gas turbidity. Irwin and Stevenson (1951) were successful in remo

colloids from pond waters by adding vegetation. As this material mposed, carbon dioxide was evolved and carbonic acid formed. acid, which is almost wholly dissociated under such conditions, l hydrogen ions for combination with the negatively charged micelle, resulting in their precipitation.

Reducing conditions in the muds of the marshes studied have sted throughout most of the growing season. Thus, the fermenta- of organic materials and the resultant production of carbon de has significant influences on the solubility of several essential ents. Under such conditions: ferric and manganic compounds d be reduced to the soluble, divalent forms: the solubility of ssium should be enhanced: phosphorus combined in insoluble with calcium and iron may be released: calcium and magnesium d be brought into solution as bicarbonates; and carbon dioxide uced would be available for use by photosynthesizing plants. This simplified explanation of the interaction between organic matter part of the biochemical dynamics of marsh environments serves ally to catalogue some of the relationships observed. Further, concept furnishes a starting point for evaluating some of the lems posed by commonly suggested marsh management practices.

## MARSH MANAGEMENT

Marsh management, as here used, implies the selection and lopment of more or less dry land to create a shallow-water onment and the regulation of such habitat for wildlife. Essen- this involves control of chemical and/or biochemical factors h influence plant growth, but it also includes site selection and nstallation of mechanical structures for regulating water depth. ;ical starting point is selection of sites for development.

### sh Site Selection

The topography of the area to be flooded should be nearly level have marginal contours widely spaced. Sites with well defined ins will eventually lose an important property—much of their ated edge. The periphery of a marsh is usually considered the important portion for wildlife. To the marsh manager, then, election of sites for development which, when flooded, will have l, shallow marginal areas is of real significance.

The influence of flooding woody vegetation, which is destroyed ie change in water level, or of water transparency and water

depth, as these two factors influence light penetration, is too
known and understood to need further elaboration. However,
presence of numerous trunks and branches of dead trees and h
on the marsh soils may effectively reduce the area available for p
growth (Figure 24).

Figure 24. A result of flooding woody vegetation. The Lippencott M
drained after being flooded for 6 years. Note space occupie
undecomposed material and the virtual absence of any re
emergents.

The general success of agricultural practices in the vicinit
a site, and hence the quality of drainage area soils, is a reason
basis for predicting the success of a created marsh for wildlife. G
quality agricultural soils are usually kept within a favorable pH ra
for crop production, and, in addition, high fertility levels are m
tained. Part of the lime and fertilizers added, plus part of the in
nutrients of the soil, should reach the marsh basin through percol
and runoff water. Thus more favorable chemical balances shoul
expected for marsh environments surrounded by good agricult
lands than for those which receive drainage from degraded soils.
evidenced by data presented earlier, there has been an accumula
of essential elements in all the marsh basin soils studied, altho
this is contrary to the conclusion of Hartman (1949) that gro
vegetation exhausts soil nutrients.

It has been noted, not only in the Northeast but elsewhere,
marshes which lose a relatively large portion of their water res
during the growing season through evaporation and transpiration

productive of desirable food and cover plants than those which tain a uniformly high water level. Thus the mean annual rain- n areas where marshes may be developed as well as the yield ater from the drainage area during the growing season are impor- considerations in site selection. While an appraisal of water yields drainage areas is beyond the scope of this paper, Brumsted 4) has presented much pertinent information on this subject.

### er Regulation

After a site has been selected for development, structures to be oyed to regulate the water level may be considered. Concen- ons of plant nutrients, as indicated in part by total alkalinity, ase with depth except during brief periods in spring and fall. tures designed to remove surface water as opposed to subsurface ottom water, would be in keeping with wise fertility management. While frequent marsh drainage may be fraught with certain ers, aspects of which will be considered later, drainage may be nly practical solution for temporarily revitalizing marsh soils. nage may be necessary also for dike repairs, for removing dead, y material from the marsh floor and as an aid, among other s, for "conditioning" the soil to prevent an early return to a vely nonproductive state after reflooding. To effect internal soil age, the drain pipe (trickle tube) through the dike should be st a foot lower than the general marsh floor.

### ting Aquatic Vegetation

The absence of desirable vegetation in certain shallow-water onments may be attributed, in some instances, to a dearth of species in the drainage of which the marsh is a part. Before ings are attempted, one should first determine the capacity of nvironment to support such plants. Specific requirements for ic plants are poorly understood, except for rice, and test plant- to obtain a biological "assay" of conditions would be a wise dure. Results should be viewed with caution, however, even h test plantings may survive in physiologically "old" marshes.

### ng

Not all problems of marsh management relate solely to physical chemical characteristics of the environment. Maintenance of g is a case in point. Public relations are often involved also.

Water for these environments is in most instances only that s
plied as runoff or as percolation through the soils of the drain
area. Thus, for the summer season, discharge through the spill
should not be expected. Lack of replacement when coupled v
strong thermal stratification (summer stagnation and winter stag
tion) may not be favorable for fish. In addition, large amounts
organic materials exert an intensive demand on the oxygen rese
Nevertheless, introduction of fish in marsh waters, either as a sin
species or as a combination, has been the rule for nearly all those
which information is available.

Data obtained in 1954 and 1955 point to the conclusion t
oxygen demands for the first year following flooding are higher th
those for the second. This is to be expected. Much organic mate
is usually submerged at the time of initial flooding and, in its dec
position, uses up much of the available reserve. It follows that sto
ing with fish the first year of flooding is more apt to result in fail
than would stocking in subsequent years.

The dissolved oxygen in marsh waters under ice cover is ap
reach critical levels and remain low or entirely absent for exten
periods, usually until a thaw replaces oxygen-depleted waters. D
obtained suggest that melt water flows along definite channels rat
than as a sheet over the entire marsh floor. Such oxygen-satura
or super-saturated water, concentrated in regular flowages, can sat
biochemical demands for the restricted area through which it mo
and still hold an appreciable reserve for as long as a week or possi
longer. During this study, winter fish kills were observed but on
At this site no oxygen was detected in the water column and p
sumably the loss of fish (bullheads and bass) could be attributed
this lack.

Of the sites studied, none consistently maintained low eno
temperatures or a sufficiently high oxygen content to support tr
However, as the borrow pits were excluded from an appraisal of c
ditions in marshes, the deeper waters of such locations might supp
these fish.

In the management of marsh environments for wildlife, regu
tory measures suggested earlier probably would be detrimental
fish and fishing. The encouragement of emergent vegetation by red
tion in water levels would usually raise bottom temperatures;
chemical activity would normally be increased and oxygen dem
intensified. Emergents, by their presence, might inhibit fishing succ

Drainage, to assist in establishing a balance in nutrient s

be complete. That is, the water must be removed from over the and the soils drained to field capacity or to the fullest extent will result from drainage by gravity. Such a practice would with disfavor with landowners who had made the effort to estab- sports fishery.

Removal of water from artificial impoundments to fill a variety arm needs is increasing at an ever-accelerating rate. While a ively high proportion of irrigation water might be returned to flooded basin in the humid Northeast, such reductions in total r reserve, when added to natural losses, could result in the elimi- n of fish in marsh environments. To date, the amount of water ved, particularly for irrigation, has not been great in New York. he future, it may represent a problem in both fish and game agement.

### mical Relationships

While physical and public relations problems of marsh manage- may be solved with relative ease, chemical aspects are less easily ted and usually much more difficult to correct. A wide variety ch factors has been discussed in the literature. We are justified nsidering some of these even though present knowledge of them gely in terms of rice culture.

First, it is evident from data presented on soil analyses, and a review of the studies of Hoagland (1948), that the primary ronutrients) and part of the secondary (micronutrients) ele- s were not limiting to plant growth because of scarcity. Also, is no indication that those elements (secondary) not included e analyses were absent or present in such low quantity as to be ng. Indeed, agricultural crops respond favorably without the ion of any of the secondary elements, save, perhaps, as impurities rganic fertilizer, in the area of the State covered by this study.

With respect to rice soils, special attention has been given by and Sturgis *(op. cit.)* and Bonner (1950) to toxic concentrations rite nitrogen and by Vlamis and Davis (1944) and Chang and is (1945) to those of carbon dioxide. Hydrogen sulfide toxicity een evaluated by Mitsui *et al.* (1951). Many studies have been rned with the role of manganese as a growth inhibitor, and s and Clark (1950) as well as Tisdale and Nelson *(op. cit.)* suggested the relationship between soluble manganese and iron. e latter Ponnamperuma *(op. cit.)* in designating the chief limit-

ing factor in the production of rice stated, "All the available evide suggests that it is iron . . . First, in a highly reduced soil the con of reduced iron is normally far in excess of reduced manganese, alternative candidate for the role of toxic factor. The lower solub of ferrous hydroxide, carbonate and sulfide is no bar to the prese of large amounts of iron in solution because of the ease with wh iron forms soluble complexes with the products of anaerobic dec position of organic matter." Wilde *et al.* (1950) stated, "The accu lation of ferrous iron leads to the fixation of phosphorus in insol form." While this conclusion is not compatible with data presen earlier on the increase of phosphorus after the flooding of marsh s or with the work of Mortimer *(op. cit.)*, Ponnamperuma *(op. c* and others, their conclusion that 50 p.p.m. of soluble iron constitu a high level is worthy of consideration.

Plants growing on marsh soils strongly supplied with iron excess of 200 p.p.m.) frequently exhibit symptoms of iron deficie i.e., chlorosis or yellowing of the leaves. This anomaly has explanied by Curtis and Clark *(op. cit.)* who concluded, ". . . chlor appears when an excess of manganese is present. This is consid by some as due to oxidation by manganese of iron in cells to insoluble ferric form . . . an excess of iron, on the other hand, ind symptoms of manganese deficiency."

The only definitive work that has come to our attention on requirements of aquatic plants is that of Ponnamperuma *(op.* who concluded that a concentration of about 25 p.p.m. was requ in rice soils. Evidence that wildlife marsh soils may contain m times this amount has been presented.

Iron and manganese behavior patterns in submerged soils essentially alike, except that manganese reduces more readily an more difficult to oxidize, and that manganous sulfide is not prec tated over commonly observed pH ranges (Ruttner, *op. cit.*). evident, therefore, that measures to control iron would result in no parallel changes in manganese. Consequently, in the following cussion considerations will be limited, generally, to iron.

There are several natural checks on the concentration of element in soluble form in submerged soils. It is clearly evident a large proportion of ferrous iron would be oxidized to the fe state in the presence of oxygen. Yet, as the water in marsh- environments may contain dissolved oxygen only at brief periods ing the spring and fall, the oxidized portion of the submerged would then be limited to the first few millimeters only.

Van Raalte (1941) has demonstrated that the roots of aquatic
nts give off oxygen and that the environment immediately sur-
nding such roots would be characterized by oxidation rather than
uction. Indeed, the brown iron deposit on the roots of healthy
atics attests to this process. Yet, it is self-evident that high con-
rations of reduced iron could rapidly overcome this oxidizing
ier. The point at which this would take place is unknown and,
ause of variables, may never be defined for the wide variety of
nts that have an affinity for shallow water. This protective mechan-
may help explain why certain plants, such as the waterweeds
*acharis)*, meadowsweet *(Spiraea)*, buttonbush *(Cephalanthus)*
the curly-leaf pondweed *(Potamogeton crispis)* can tolerate high
centrations of this metal in solution.

The degree of water loss by evaporation and transpiration may
such that much of the submerged soils will be exposed and aerated
ing the growing season. This natural control of iron may be of
ular importance in the selection of sites for marsh management
ause under such conditions valuable crops of food and cover plants
be expected annually without soil treatment.

Hydrogen sulfide, itself toxic, tends to lower concentrations of
soluble iron and manganese by forming ferrous or manganous
de. Mortimer *(op. cit.)* and Misra (1938) could detect no free
rogen sulfide in strongly reduced lake muds although ferrous sul-
was present. Shioiri and Yoshida (1951) reported that injury
ice from hydrogen sulfide occurred only in degraded soils which
extremely low in soluble iron and manganese. Baba *et al.* (1952)
luded that hydrogen sulfide is precipitated chiefly as a ferrous
de for soils high in soluble iron. Thus it is evident that hydrogen
de serves as a protective mechanism in the control of these
als in solution, as ferrous sulfide is only sparingly soluble in water
0062 gram per 100 milliliters at 18° C.) and manganous sulfide
ven less so (0.00047 gram per 100 milliliters at 18° C.). The
rse relationship would also be true.

Einsele (1940), referring to soluble iron in lake soils, gave the
mum pH for solubility as 6.5, but stated that at pH 7.5 little
into solution. There is a widespread belief in the Northeast that
conditions in submerged soils cause non-productivity in marshes.
ele's thesis supports this belief.

### inage and Soil Aeration

In the artificial management of aquatic environments drainage

has held a dominant place. For fish ponds Schaeperclaus (1933) defined drainage procedures and expected results. In a review of t work, however, it is clearly evident that fertilization, with orga or inorganic fertilizers or both, was commonplace before refloodi

Pearsall (1950) mentioned some of the problems that may acc pany the drying of wet soils. He concluded: that when waterlog soils are dried, iron-humus complexes are formed; that there i reduction in the exchange capacity of the soil; that there is a for tion of humic colloids which are acid in reaction; and that the hu colloidal mass is microbiologically inert. He cautioned, "Drying extreme aeration is thus likely to produce harmful results in wet soi

From data presented earlier, which indicate a reduction, foll ing initial flooding, in total nutrient salts held by the soil, one m infer that a substantial portion of what is lost to the soil accumul in the water mass and is held in solution or suspension, or is inc porated into living tissue. The alternate source of loss, that tra ported by vertical and horizontal water movement, would not sufficient to account for the change. If it were, marsh basin s which in general are poorly drained before flooding, would be seve leached. Analyses indicate that they were not. It follows, therei that water removed during drainage would carry with it much o total burden of nutrients. Frequent drainage could deplete serio the fertility of marsh environments.

This hypothesis is not without support. Robinson (1930) sta "The solubility of lime is so high under submerged soil condit that such a soil would soon lose all the lime it contained, provi of course, there was a movement of the solution or movement of l by diffusion." What applies to lime would, in a lesser degree, a to other essential elements dispersed in water, i.e., they would carried by water movement.

Annual drainage may eventually result in a vegetative com of low value to wildlife as indicated by McLean (1957) who conclu that yearly reduction in the number and size of desirable ann was due to competition from perennials. Yet, it is possible that change was related to a more fundamental cause, that of soil ferti

During the study reported here perennials were the most frequ invaders in the scalped, shallow-water portions of borrow pits. T soils, in general, represent the "C" horizon of the soil profile, are usually poor in nutrient salts. However, growth requirem for aquatic plants are, at best, poorly understood. Yet, it seems

that perennials, which could develop a more elaborate root sys-
with each succeeding year, would be more efficient in absorbing
ssential salts that were available than would annuals, especially
g the initial growth stages of the latter. Thus, the establishment
ominance by annuals may be related to the fitness of the environ-
to support them.

Drainage, when practiced annually, appears to be a drastic meas-
nless accompanied by costly fertilization. A well-designed drain-
program, on the other hand, has merit, especially when employed
njunction with other practices.

An obvious question is, what is accomplished by marsh drainage
soil aeration? Only a partial answer is possible with the data
able.

Major changes occur in the organic content of marsh soils when
are exposed to the air during summer as indicated by studies
rning the settling of peat soils. Organic matter has a profound
nce on the solubility of several essential elements, among them
and manganese. Robinson *(op. cit.)* reported that in the absence
ganic matter the solubility of iron, manganese, calcium and
nesium was not increased by soil submergence. Ponnamperuma
*cit.)* concluded that a combination of pH near neutrality, the
nce of nitrate nitrogen, and the absence of excessive organic
r and drainage were conducive to high yields of rice. Misra
*cit.)* found that the amounts of exchangable iron and manganese
negligible in inorganic muds. In the production of rooted
ics the evidence indicates clearly the desirability for controlling
ic matter content in submerged soils and thus, indirectly, regu-
soluble iron and manganese.

Drainage, by itself, must be considered of temporary value.
nson *(op. cit.)* in speaking of submerged soils stated, "In general
concentrations of iron are developed in eight days. Concentra-
of manganese sufficient to be toxic are not always developed
s time . . . it is probable that soils submerged under field con-
s would develop toxic concentrations of manganese and iron
nsiderably less than eight days." Yet, it is evident that concen-
ns toxic to rice may not always limit the growth of desirable
ics in wildlife marshes. Good to excellent results in New York
been observed for two years following drainage, but the trend
this time was toward a sharply lowered production of desirable
ation.

Einsele *(op. cit.)* has determined the optimum pH for the p duction of soluble iron to be 6.5. Thus, it is clearly evident t drainage and soil aeration, followed by judicious applications of li has a definite place in the management of shallow-water environme In determining the amount of lime to add to aerated marsh soils, must realize that the cation adsorption capacity increases sha with the content of organic matter in the soil, i.e., organic soils strongly buffered and thus offer marked resistance to change in Therefore, relatively great amounts of lime must be added to ef a base saturation of 100 per cent or to raise the pH above 7.5, ass ing applications of calcium and magnesium carbonates only. use of sodium salts, while they would be more efficient in raising should be viewed with caution because of possible side effects. H again, much field experimentation is necessary.

Comparison of drainage area and marsh basin soils suggests substantial amounts of essential nutrients particularly calcium received from the drainage area. If aerated marsh soils were bro to 100 per cent base saturation with lime before reflooding, it se reasonable to assume that the yield of this element from a drain area of good agricultural soils would satisfy the demand created the annual replenishment of organic matter for at least five yea the marsh basin were not drained during this time.

Nutrient loss by drainage may be held to a minimum. Du periods of the year when isothermal conditions prevail, the oxy system would exert a strong influence on the concentration of sol in the water. Many of these would be precipitated at such ti (Mortimer, *op. cit.*). Moreover, in the fall just prior to ice format plankton abundance would be low (Sverdrup *et al.*, 1942), and drainage limited to the fall would be less costly, in terms of nutr losses, than drainage at other seasons.

Changes in the concentration of nutrient salts are not r following fall drainage, as indicated by the tabular summary alr presented. During the period when soil samples were collecte was evident that soil drainage had not been completed even thc the overburden of water had been removed. Thus, anaerobic co tions were maintained within the soil system and reducing condit prevailed. Consequently, winter drainage in localities where the face of the mud freezes does not lower concentrations of soluble m to the extent deemed desirable (less than 50 p.p.m.). Therefor seems necessary to withhold water from the marsh basin during succeeding growing season.

ILIZATION

Fertilization of marshes is another aspect of management that may valuated. McLean (*op. cit.*) obtained good to excellent results ie addition of soil amendments to the low-grade, sandy soils in al New Jersey. Hartman (*op. cit.*) considered Wisconsin flowages deficient in nutrient salts. Marsh soils in New York, on the hand, have been shown to be richly supplied with nutrients in bsence of drainage.

In this discussion it is assumed that there is no scarcity of trace nts that would be limiting. Comments will be limited, therefore, ie essential nutrients generally added in commercial fertilizer, itrogen, phosphorus, and potash.

The yield of nitrogen to marsh soils from a drainage area is of order (Lyon & Buckman, *op. cit.*). Precipitation may add conable amounts of this element as nitrate and ammonia. Ruttner *cit.*) estimated that (at Lunz, in Austria) rainwater contained t 0.36 milligram of nitrate and ammonia nitrogen per liter. Fixamay be of primary importance; Ponnamperuma *(op. cit.)* cited nce that *Anabaena cylindrica* may fix nitrogen at a rate of 480 ds per acre per month. Other blue-green algae may also fix this nt. Fixation by algae is increased by a moderately alkaline on and by addition of phosphates; it is depressed by supplemental ies of nitrogen.

The results of soil sample analyses reported here indicate that gen is abundantly available in marsh soils. The heavy growth lges *(Cyperus)* and smartweed *(Polygonum)* following soil drainnd aeration furnishes added support for this conclusion. The ice suggests that little would be gained by adding nitrogen rtificially.

The value of adding phosphorus to marsh soils remains an open on. Schaeperclaus *(op. cit.)* referring to fish pond fertilization nade the exceptionally strong statement. "The most profitable zation as already stated is always a fertilization with phosphorus." ott (1951) concluded, "Although there is conflicting evidence ling the role that phosphorus plays as a controlling factor in the opment of aquatic floras, many critical studies indicate that it egulator."

Rice grown on submerged soils seems to need little phosphorus (Gericke, 1930). Bartholomew *(op. cit.)* suggested that 0.3 . is adequate if this concentration is maintained. Ponnamperuma

*(op. cit.)* concluded that it would be impractical to add phospho to rice soils because it would become abundantly available after flo ing. Phosphorus demand by decomposing vegetation was considd by Acharya (1935) who concluded that rice straw itself contai enough phosphorus (0.42 per cent) to satisfy requirements of anaero digestion.

Barrett (1952) noted that the fertilization of a lake with phosp rus did not increase the phosphorous content of the water. He c cluded, ". . . with high alkalinities the residual phosphorous centages are lower. Although other variables . . . may also have h significantly related to the disappearance of phosphorus, the pre study provides strong support for the general hypothesis of the im bilization of phosphorus in natural lakes by calcium."

Ruttner *(op. cit.)* offered another explanation. He conclu that when ferrous iron and phosphate occur together in the hy limnion of lakes, an insoluble ferric phosphate is precipitated w oxygen is introduced. Conversely, when reducing conditions e the ferric iron would be reduced to the ferrous form and phospho would be again freed to go into solution.

Other workers have concluded that soluble phosphorus is ta up by plankton and thereby removed from the water, at least t porarily.

The level of phosphorus noted in this study, in most insta near 0.5 p.p.m., could not be expected to remain constant. diverse and often interrelated demands for this essential are of s complexity that is is difficult to evaluate its influence when added marsh soils. Here much laboratory and field experimentation is nee Potash is generally low in organic soils yet rather large amounts to 100 pounds per acre per year) may be carried by water fro drainage area (Lyon and Buckman, *op. cit.*).

Aiyra (1948), Mitsui *et al. (op. cit.)* and Baba *et al. (op.* have considered the fate of potassium following soil submerge changes in plant metabolism associated with potassium deficie the existence of antagonism in absorption between iron and potassi and the effects of the presence of hydrogen sulfide on absorptio potassium. The concentration of potassium in solution in marsh has been favorable when related to the amounts required in w cultures. Moreover, drained and aerated marsh soils have suppo luxuriant crops, thus indicating that this element was not limitin

The addition of liming agents, as already noted, may improve growth potential of flooded soils in a variety of ways. Among t

nportance are the establishment of a strong buffer, the release by action of other essential cations from the colloidal mass, an leration in the breakdown of organic matter, better regulation or nce of iron and manganese, and improvement of the availability lcium and magnesium as essential salts.

Adequate answers regarding the need for addition of fertilizers require further field experimentation. In the absence of such vledge, the necessity for fertilizing marsh soils is not indicated ie data presented in this paper. The judicious addition of calcium magnesium carbonates, on the other hand, would appear to be ngular importance.

The productive potential of properly managed marshes is seldom lled by that of other wildlife environments. Moreover, such ow-water areas may support an almost limitless variety of life, in form and abundance. The ever increasing need for water riculture serves to emphasize the importance of artificial impound- ts, and in terms of fresh-water management such areas could play hly important role.

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# COMPARISON OF ESTIMATES OF FISH POPULATIONS IN LA

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ABSTRACT

Population studies involving a number of fish species, but carp prim
were carried out in three lakes ranging from 30 to 800 acres in size. Diff
sampling techniques were used and the data were analyzed by both
Schnabel method and direct proportion.

In 30-acre East Masonville Lake, sampling was done by electric sho
and an estimate of the fish population was calculated by the Schnabel me
Following this, the lake was treated with rotenone and the fish popu
was estimated by direct proportion based on the number of marked fi
sample collections. The total population was also determined by tallyin
aggregate number of dead fish collected. Estimates by direct proportion a
closely with the total dead fish collected, but those by the Schnabel metho
far short. This phase of the work also demonstrated the relative efficien
night shocking for fish collecting, the superiority of rotenone as a rela
non-selective tool, and the need for a waiting period of more than 3
between marking and recapture to allow for proper redistribution o
marked fish.

In 800-acre Waneta Lake, electric shocking was used to capture
which were then marked and released. After an interval of 40 days, sa
was done both by electric shocking and by seining. Population estimat
direct proportion were considered to be reasonably accurate using the
from either method of sampling.

Comparison is made with estimates by the Schnabel method base
approximately 23,000 and 13,000 fish of all species marked in Lamoka
Waneta Lakes, respectively. Trap nets were used exclusively in this
Sampling by this method proved not sufficiently random, and results
considered unreliable.

It is concluded that estimation by direct proportion, based on a rela
small number of marked fish, random sampling, and a substantial in
between marking and sampling, will give sufficiently accurate results for
practical purposes.

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One of the biologist's most useful tools is the population esti
For fish populations, despite intensive work by a number of inves
tors who have made marked improvements in techniques, acc
estimates are usually difficult, and often impossible, to obtain.
felt that the studies described here provide bases for further evalu
some of the present methods of population analysis, and also
suggestions for obtaining estimates more efficiently.

These studies were originally intended to aid in evaluating
effect of carp removal on the population of surviving carp
associated fish species, and on the vegetation present; in themse
they represent the situation before such removal. Estimates
made by a continuous mark and recapture method, as well as by c

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[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-

ortion. The fish were captured by trap net, seine, and electric er, and were marked by fin clipping. In one lake (East Mason- a complete kill of the fish population by use of rotenone gave an ate basis for comparison with prior population estimates.

## ESTIMATES BASED ON ELECTRIC SHOCKING AND USE OF ROTENONE IN EAST MASONVILLE LAKE

Estimates of the fish population in 30-acre East Masonville Lake laware County were undertaken in 1955 using an electric shocker sting of several 7-foot electrodes suspended from a wooden scow powered by a 230-volt alternating current generator. This equip- has been described by Loeb (1957). The water of this lake is vely soft, having a total alkalinity of 20 p.p.m. (maximum) and stivity of 22,500 ohms per centimeter cube at 70° F. The lake cked at the mouth and has a few tiny, intermittent tributaries. mum depth is 9 feet. Vegetation was almost completely lacking 55.

During a 3-week period in April 1,205 small carp, 43 large carp, llow perch, and 77 smallmouth bass were taken, marked by fin ng and released. They were taken mostly in daylight around the ine, a large proportion of the small carp being taken from schools outlet bay. All were released in the center of the lake.

Population estimates were attempted from these data using the bel formula (Schnabel, 1938). Obviously, too few perch, bass, arge carp had been marked and released for accuracy by this od. However, it was thought that a sufficient number of small had been marked and that 3 weeks would have been ample time ese fish to have become well distributed in so small a lake. Cal- on gave an estimate of 19,857 for the small carp population e 1) -a figure considered at the time to be reasonably accurate. t, because almost all fish in the lake were stunted, and the lake was regarded as relatively infertile, a population equivalent to ximately 200 pounds per acre was thought to be high.

On July 12, 1955 (almost 3 months after marking had been ter- ed) the lake was treated with rotenone, and a complete kill was ed. On that day, 11,491 small carp, 279 large carp, 1,333 and 126 bass were collected. All fish were examined for marks. ximately 38 per cent of the marked small carp, large carp, erch were collected. Only 12 per cent of the marked bass were ed. From these figures, the population was estimated by direct

Table 1. Estimation of Carp Population in East Masonville L Based on Data Obtained by Electric Shocking and Use Rotenone

| Date | Number of carp captured* | | Estimate of population§ |
|---|---|---|---|
| | Unmarked | Marked | |
| **Electric shocking†** | | | |
| April 7 | 45 | 0 | .. |
| 8 | 247 | 0 | .. |
| 11 | 667 | 7 | 29,703 |
| 12 | 16 | 0 | 31,895 |
| 13 | 12 | 0 | 33,567 |
| 14 | 7 | 0 | 34,554 |
| 15 | 7 | 0 | 35,548 |
| 18 | 35 | 0 | 40,553 |
| 22 | 169 | 17 | 19,857 |
| **Use of rotenone‡** | | | |
| July 12 | 11,033 | 458° | 30,233 |

* Includes only carp 5.6 to 9.9 inches in total length.
§ Estimates from electric shocking made by Schnabel method; those use of rotenone made by direct proportion.
† All shocking done during daylight hours, except on April 22 when d was operated for 2 hours around shore. Most of carp captured on 7, 8 and 11 were taken from schools in outlet bay.
‡ Figures for carp captured represent dead fish collected.
° Represents a return of 38 per cent of marked small carp in lake.

proportion to be 30,233 small carp, 706 large carp, 3,466 perch 1,078 bass.

On the following day, most (possibly all) of the remaining rose to the surface, floated to shore, and were also collected. number of small carp was judged as 20,000 based on tubs of collected after determining the approximate number per tub. total for the two days (31,491) very closely approximated the nu estimated from the marked fish collected, and greatly exceeded derived by the Schnabel formula. Similar agreement was found the other species.

On the day of treatment, 4 pikeperch and 24 bullheads were collected. It was arbitrarily assumed that these fish represente per cent of the actual populations (because approximately 40 per of marked small carp, large carp and perch had been collected) w would then have been 10 and 60; actually 10 pikeperch and 65 heads were collected.

It is felt that the estimates based on the number of marked fish ered after rotenoning are quite accurate for several reasons. Estimates and actual collections agreed closely. (2) Indications hat virtually the entire population of fish was collected, since sh (other than young-of-the-year) were seen in shallow water ie second day, or rose thereafter. The uniform water tempera- of 80° F. probably accounted for this almost complete collection. There was no recruitment to any of the populations marked. length-frequency curves of fish captured during the period mber 1953 to July 1955 revealed the status of growth of the d carp. They ranged from 5.6 to 9.9 inches in total length; odes were all 8 inches. Their average length increased less than inch per year. A few scale readings (from 22 specimens) indi- that this stunted group was 5 to 7 years old. No young carp killed by the rotenone. (4) Several thousand young-of-the-year and bass rose to the surface 2 days after the lake was treated. were all less than 2 inches in length and easily distinguishable the older fish.

Apparently the 3-week period of mark and recapture was insuf- t for the distribution of marked fish to become random through- ie pouplation, even in a small lake. The reasons for the poor bution can only be guessed at. Possibly the marked fish were which were originally more susceptible to shocking, although would probably be a less decisive factor than susceptibility to re by nets. Or the marked fish may have been weakened by iginal shocking and handling, and thereafter more easily caught. , the marked fish may have merely returned to the shoreline they were originally taken, instead of mixing with the popula- roughout the lake.

f the study had been continued for twice the period (6 weeks), fish would have been marked, distribution would have been r, and the estimates would probably have been higher and more ite. This, however, would have doubled the effort.

Accurate figures could have been obtained in this lake with much fort. Rotenone treatment (while not feasible in many waters) led an effective method of recapture by which complete dis- on of its effect compensated for all error which might have d from poor fish distribution. Consequently, the size of the nd perch populations was accurately determined on the day of ient even though very few fish had been marked. With respect p, the prior marking of only 250, for example, would probably

have been sufficient. The necessary number of carp, bass and pe could probably have been captured in only two full nights if o night shocking had been used. On the day of rotenoning, far fe fish could probably have been collected with equally accurate e mates. Thus, the work of 3 or more weeks could have been reduced 3 days.

These data suggested two things. First, continuous mark a recapture studies are too expensive since they must be carried for long periods of time for accuracy. Second, it would appea be better to mark fewer fish (within limits), wait a longer period allow for random distribution of the marked fish, and then recap a small number for estimating the population by direct proporti The recapturing method would, of course, automatically sample entire population if mixing of marked fish were random.

Accordingly, this procedure was adapted to a study of the c population in Waneta Lake.

## ESTIMATES BASED ON ELECTRIC SHOCKING AND SEINING I WANETA LAKE

Waneta Lake (800 acres) has a total alkalinity ranging from to 90 p.p.m. and a resistivity of 5,500 ohms per centimeter cube 70° F. Maximum depth is 32 feet. Vegetation was abundant at time this work was done.

An electric shocker was operated from May 24 to June 15, 19 During this period 546 carp (12 inches and over in total length) w captured at night in the shallow areas. Of these, 512 were mar and randomly released in the areas of capture.

Using the Schnabel method the carp population ranged fr 2,915 to 7,599 (Table 2). If the continuous mark and recapt procedure had been carried out for a longer period, the final estim would undoubtedly have been higher. However, marking was a trarily terminated at that point. The data obtained were proba influenced by a poor distribution of marked fish, since the sho was operated throughout the considerable shallow areas of the lake

Seining was begun after an interval of 40 days from the t marking ended and was continued for a period of 22 days (July to August 16). In 19 hauls with the seine (the last haul being m with electrified equipment) in three widely separated areas 425 c were captured, 12 of which had been marked (Table 3). Direct p portion estimates of the population ranged from 15,053 to 18,

E 2. ESTIMATION OF CARP POPULATION IN WANETA LAKE BASED ON DATA OBTAINED BY ELECTRIC SHOCKING*

| Date | Number of carp captured | | Estimate of population§ |
|---|---|---|---|
| | Unmarked | Marked | |
| May 24 | 105 | 0 | .. |
| 25 | 105 | 3 | 3,780 |
| 26 | 52 | 5 | 2,915 |
| June 1 | 79 | 2 | 4,453 |
| 6 | 65 | 2 | 5,615 |
| 7 | 102 | 4 | 6,901 |
| 15 | 22 | 0 | 7,599 |

ll shocking done at night; entire shoreline covered.
stimates made by Schnabel method.

l on the cumulative catch at different dates. All captured fish destroyed.

During the period August 18 through August 31, 687 carp were ured by electric shocking at night; 24 of these fish had previously marked. Population estimates ranged from 10,240 to a final e of 14,656, with each estimate based on fish caught (shocked up to that time and determined by direct proportion. All arked fish under 15 inches in total length were excluded from stimates as an arbitrary compensation for growth. No marked nder 15 inches in total length were recaptured.

If the data from both seining and shocking are considered together day to day basis, a final estimate of 15,815 is obtained that is ably more accurate than the 18,133 for seining alone or the 6 for shocking alone. All three figures are considered to be ate enough for the original purposes intended.

The proportion of recaptures by the two methods (Table 4) e tested for independence by chi square. As the value obtained y 0.38 (to be significant at the 5 per cent level, chi square must least 3.841), it is evident that seining and electrofishing were ling in a homogeneous fashion. It follows that estimates made endently by these two methods apply to the same population.

Length-frequency curves show that all size groups of carp above ches in total length were sampled randomly throughout the study.

TABLE 3. ESTIMATION OF CARP POPULATION IN WANETA LAKE BASED DATA OBTAINED BY SEINING AND ELECTRIC SHOCKING*

| Date | Number of carp captured§ | | Estimate of population† | Remarks |
|---|---|---|---|---|
| | Unmarked | Marked | | |
| **Seining** | | | | |
| July 26 | 66 | 0 | .. | 1 haul –southwest shore<br>2 hauls—east shore |
| 27 | 76 | 5 | 15,053 | 2 hauls—north shore |
| 28 | 48 | 1 | 16,725 | 1 haul—north shore |
| 29 | 67 | 2 | 16,960 | 1 haul—southwest shore<br>1 haul—north shore<br>1 haul—east shore |
| 30 | 59 | 1 | 18,489 | 1 haul—southwest shore<br>1 haul—north shore<br>1 haul—east shore |
| August 4 | 32 | 2 | 16,710 | 1 haul—southwest shore<br>1 haul—north shore<br>1 haul—east shore |
| 5 | 15 | 0 | 17,408 | 1 haul—east shore<br>1 haul—north shore |
| 6 | 39 | 1 | 17,664 | 1 haul—southwest shore |
| 16 | 11 | 0 | 18,133 | 1 haul—southwest shore |
| **Electric shocking** | | | | |
| August 18 | 57 | 3 | 10,240 | South end and Wayne Chan |
| 19 | 146 | 3 | 17,835 | South end |
| 22 | 69 | 1 | 20,407 | East, west shores and north e |
| 23 | 14 | 1 | 18,816 | Entire shoreline |
| 24 | 108 | 2 | 20,685 | West shore |
| 25 | 119 | 10 | 13,645 | West shore and north end |
| 26 | 128 | 4 | 14,186 | West shore and north end |
| 29 | 17 | 0 | 14,549 | Entire shoreline |
| 30 | 1 | 0 | 14,571 | Entire shoreline |
| 31 | 4 | 0 | 14,656 | Entire shoreline |

* All seining and shocking done at night; on August 16, seine and elec seine device used.
§ Includes only carp over 15 inches long.
† Estimates made by direct proportion.

LE 4. COMPARATIVE NUMBERS OF CARP TAKEN BY TWO METHODS IN WANETA LAKE

| Method | Number of carp taken | | Total |
|---|---|---|---|
| | Unmarked | Marked | |
| ng | 413 | 12 | 425 |
| ric shocking | 663 | 24 | 687 |
| l | 1,076 | 36 | 1,112 |

Several factors are emphasized by the carp population work in neta Lake. Once again, it is obvious that sample size is relatively nportant if the fish are randomly distributed (sample size should bably be increased in larger waters). In this phase of the study, 512 carp were marked and released, yet that number was suf-nt to provide what apparently are sufficiently accurate population nates by two independent methods of recapture. In this instance, aiting period of 40 days between termination of marking and ation of recapturing was sufficient to allow random distribution arked fish.

Although independent estimates by seining and shocking are able because they check each other, it is obvious that either esti-e would have been satisfactory. Use of different methods for king and recapture to eliminate bias has been discussed and prac-d for years (Ricker, 1948). Usually the second method used for pture gives more accurate and often higher estimates than would peat performance by the original marking method (Lawrence, 2).

Nevertheless, in this instance the estimate obtained from recap-s by shocking may also be considered as close to the actual popu-n with a large degree of confidence. This may be due to the aracteristics of the technique itself, since electric shocking is prob-less affected by the behavior of the fish; in addition, all shallow s were covered by the shocker.

An important point demonstrated by this study is that equally ble estimates based on the same number of marked fish could have n obtained with much less effort. Just over 500 fish were originally ked in seven nights over a period of 3 weeks. It is estimated that, g improved techniques for capturing carp with the electric shocker eb, 1957), the same number could actually have been marked

in three nights during that time of the year. In addition, either sei or electric shocking could have been eliminated during the J August period of recapture. The 26 nights spent fishing could h been halved with equally reliable results. This period would be c siderably shorter than the time required for accurate estimates the continuous mark and recapture method used by Schnabel.

It should also be noted that pikeperch, brown bullheads, picke chub suckers and common suckers were as vulnerable to shockin carp, while alewives, bass, bluegills, and pumpkinseeds can be ta in much greater numbers. Population estimates might also be m for these species if the electric shocker were used for both capture recapture.

## ESTIMATES BASED ON NETTING IN LAMOKA AND WANETA LAKES

Although done prior to the work just described, netting studie Lamoka and Waneta Lakes are presented last for purposes of c parison. These lakes are 600 and 800 acres in size, respectively. the basis of physical and chemical characteristics (total alkali 50-90 p.p.m.; resistivity 5,500 ohms per centimeter cube at 70° both are considered to be quite productive. Maximum depths 30 to 40 feet, and both lakes contain considerable shoal area and v tation. Fish are abundant.

A dozen trap nets were employed continuously for 40 days ( ing the spring in Lamoka Lake, and for 30 days during the fal Waneta Lake. Approximately 23,000 and 13,000 fish of all spe were marked in each lake, respectively. The method used to c out the study was similar to that used by Cooper (1952) for a se of population estimates in Michigan lakes. The work was perfor with great care. The nets were lifted daily and moved to new l tions whenever possible. The crew consisted of four men.

In order to assure accuracy in making population estimate continuous mark and recapture methods in large lakes, relati large numbers of fish should be marked. Insofar as is known, n fish were marked in these studies than in any other, but, despite great effort involved, results were disappointing.

Estimates could not be made of the carp, largemouth bass, sm mouth bass, common sucker, rock bass, yellow bellied sunfish, go shiner, or alewife populations in either lake. Chub suckers, pump seed sunfish, and chain pickerel were not captured in enough num for estimation in one or the other of the two lakes. Partial su

realized for bluegills, black crappies, yellow perch, and brown heads in both lakes using the Schnabel formula.

Actually, the figures for the latter group may represent fairly irate sampling of a portion of the total population of each species. y cannot, however, be considered accurate for the lake as a whole. per (1952) found that the size of the final estimate is directly ted to the numbers of traps and stations fished (distribution of ng effort). The present studies were carried out with far fewer ing stations than were those in Michigan, although the total area ne lakes actually fished was much less. Therefore, it can be assumed an increase in the number of nets would have resulted in higher nates. Estimates would also have been higher if the data for n species had been grouped according to size of the fish, thereby ding a mathematical error (Cooper and Lagler, 1956). Too few were recaptured to permit this, however.

Final analyses of the studies indicate that netting alone for simul-ous estimation of many species is not feasible in these large ies of water. This is especially true if continuous mark and recap- methods such as that of Schnabel are used.

Netting studies are in themselves arduous, time consuming, and ensive. Moreover, they do not provide for random distribution of ng effort for most species. The Schnabel and other continuous k and recapture methods usually do not provide accurate figures n a reasonable expenditure of effort. The relationships among ulation size, rate of sampling, and time required for "accurate" nates have been clearly described by Cooper and Lagler (1956). en about 2 per cent of the total population is taken in daily tures, a good estimate is obtained in about 20 days; 1 per cent provide an estimate within 30 days. These figures are based on lts of sampling from a bean machine that randomly mixes the ked and unmarked beans. Mass netting studies do not even ely approximate these ideal conditions.

The netting studies did point out an interesting fact concerning distribution. Waneta and Lamoka Lakes are without connecting rs except for a navigable channel between them, approximately a mile in length. Of 13,000 fish captured in Waneta Lake in fall, only three had been part of the 23,000 previously marked amoka Lake.

## CONCLUSIONS

Trap netting methods intended to give concurrent population nates of many species of fish in large lakes, are arduous, time

consuming, expensive, and often unreliable. The same conditi apply to all continuous mark and recapture methods involving ma species.

Regardless of the method used (possibly excluding poisoning some instances), some species will avoid capture almost entirely. Ot species will be captured in small numbers only, possibly too few estimation. Netting, in particular, is selective insofar as size of is concerned. Even if a combination of methods is used to capt and mark sufficient numbers of fish of all species, rates of distribut of marked fish of the different species are likely to vary. For so species the marked fish may not become randomly distributed wit the period of time feasible for continuous mark and recapture ope tions. This limitation is important because, although a particu species may be present throughout the lake, it is unlikely that device used to capture it will be able to operate in a random fashi either distribution of fish or fishing effort must be random.

Direct proportion appears to be a better method of estimat populations. The effort required for obtaining estimates can be c siderably lessened by allowing for a period of random mixing marked fish before beginning recapturing, although correction m be made to offset the effects of recruitment.

Although use of different methods during marking and recapt ing operations appears to avoid some sources of bias, the elec shocker may be used for both in some instances; the shocker is pr ably less subject to the behavior of fish than is conventional netti

Vast improvements in fish-catching methods are necessary bef any easy, accurate means of estimating populations can be devised

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# REPRODUCTION IN THE FISHER IN NEW YORK

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ABSTRACT

Hand-sectioned ovaries of 39 fall- and winter-trapped fisher revealed ora lutea in 23. The mean number of corpora lutea was 2.72; the mode 3. Freshly recovered blastocysts, flushed from the uterine horns are ibed.

Corpora lutea show a high degree of vacuolation in December specimens he ovary has a high proportion of interstitial tissue.

All breeding females showed at least partial fusion of the temporal ridges e skull to form a sagittal crest, and the maxillary-palatine sutures were letely fused. Non-breeding females showed the temporal ridges in various es of separation and had the maxillary-palatine sutures at least partly

It is concluded that female fisher normally breed at the age of one year e wild, and that these criteria will separate young-of-the-year from adults. A frequency distribution of the length of the sagittal crest seemed to ate at least three age groups in the sample of 87 skulls.

Implantation probably takes place sometime in February since free blasto- may be recovered in January and possibly in early February. A 75- meter (crown-rump) embryo was recorded for March 13.

The relative abundance of fisher *(Martes pennanti pennanti)* repeated open trapping seasons in New York State in recent years made possible the collection of some data on reproduction. Little mation is available on breeding in wild fisher. They are known ate shortly after parturition in the spring (Hall, 1942) and to a gestation period of about 51 weeks. Enders and Pearson (1943) ibed some sectioned blastocysts from the reproductive tracts of ary- and February-caught specimens to establish the fact of ed implantation in this species. Hamilton and Cook (1955) nted data on the recovery of free blastocysts from wild-caught and recorded data on two non-captive litters.

For this study, data on 87 fall- and winter-trapped females were able. These data were derived from carcasses shipped in by mercial trappers; the carcasses were in various conditions of rvation--frozen, partly thawed, dried, or partly decayed. The es, as well as the skulls, of 39 of these were in condition for while the skulls of 48 others were used for comparisons. Data lastocysts, obtained by flushing the non-preserved uterine horns, available for 66 specimens.

A few ovaries were sectioned histologically but most were ha sectioned in half-millimeter slices. Corpora lutea were plainly vis macroscopically by this latter technique although all were verifie using a dissecting microscope.

## CORPORA LUTEA

The ovaries of 23 of 39 fisher had corpora lutea. All that corpora lutea were judged by skull criteria to be over 1 year old. numbers of corpora lutea per female were distributed as follows the 22 specimens having both ovaries present: 3 females had 4 cor lutea each; 10 had 3; 9 had 2; and none had only one. The n number was 2.72. This agrees closely with the figure of 2.70 g by Hall (1942) for 21 captive litters. The mode was 3 in our sam

In hand-sectioned ovaries preserved in formalin, the cor lutea appeared as typical, strongly-colored, orange-yellow bodies. M of them were 1.25 millimeters in diameter; a few were as larg 1.75 millimeters; and one measured only 0.5 millimeter. There v five instances of an equal number in each ovary — in four females distribution was 1 and 1, and in one it was 2 and 2. Eight fem had all the corpora in one ovary. Most ovaries of gravid fem showed additional bodies that, possibly, were developing or at follicles, or corpora albicantia.

In the few ovaries that were sectioned histologically at and stained with hematoxylin and eosin, some details were vis The corpus luteum of a December-caught fisher with unimpla blastocysts resembled that of the wolverine (Wright and Rausch, 19 and the marten (Wright, 1942). There was a high degree of vacu tion present. Wright (1942) suggested that this condition migh indicative of functional inactivity in such corpora. Wright and Ra (1955) noted that vacuolation disappears in wolverines with impla embryos and that the interstitial tissue becomes less prominent. cortical and medullary interstitial cells of the December fisher o were very abundant, and aside from the corpora, comprised the of the ovary. Corpora atretica and albicantia were seen in Decem specimens, as well as developing follicles in various stages, some antra.

## BLASTOCYSTS

Hamilton (Hamilton and Cook, 1955) found that he could f blastocysts from the uterine horns of many fisher carcasses as rece from trappers. Data on the presence of corpora lutea in relatio

very of blastocysts showed that blastocysts were recovered from 10 of 21 females having corpora lutea and uterine horns in a lition suitable for flushing. This is not surprising considering the lition of most of the carcasses when received. Blastocysts were vered from 9 of 14 other fisher carcasses that were judged to dult, but for which no ovaries were available for sectioning. In three specimens did the number of blastocysts obtained by flush- agree with the number of corpora in the ovaries. In all other mens where both kinds of data were available, the number of ocysts recovered was less than the number of corpora.

The blastocyst of the fisher in fall and early winter may measure uch as 1.5 millimeters in diameter. In one instance a blastocyst is size and one measuring only 0.25 millimeter were taken from same animal. An unpreserved, freshly recovered blastocyst is a transparent sphere with the inner cell mass plainly visible at one Attempts at sectioning some of these showed that the cell mass so poorly preserved that cell counts were impossible. Enders and son (1943) gave cell counts of inner cell masses from two blasto- of a January specimen and one of a February specimen of 798, and 844 cells, respectively.

The zona pellucida of the blastocysts is very thick, and is appar- responsible for their remarkable persistence in poorly preserved sses.

## BREEDING AGE

The skulls of 30 fisher females that were known to have bred ne presence of corpora lutea and/or blastocysts were examined riteria of age. All these skulls showed some degree of fusion e temporal ridges to form a sagittal crest (Figure 1). As an ional criterion the nasal bone sutures were examined, but even e oldest skulls available, as judged by the most extreme develop- of the saggital crest, the line of fusion of the two nasal bones not obliterated although the bones were consolidated. Since this of fusion remained visible in the sample of skulls available, a easily distinguishable criterion was sought. It was found that naxillary-palatine sutures on the hard palate were completely and obliterated in all breeding females (Figure 2). Examina- of 16 skulls of fisher females that had no corpora lutea in the es and, hence, that had not bred, showed that the temporal ridges widely separated throughout their length (Figure 1) in all but pecimen. In this specimen the posterior ends of the temporal

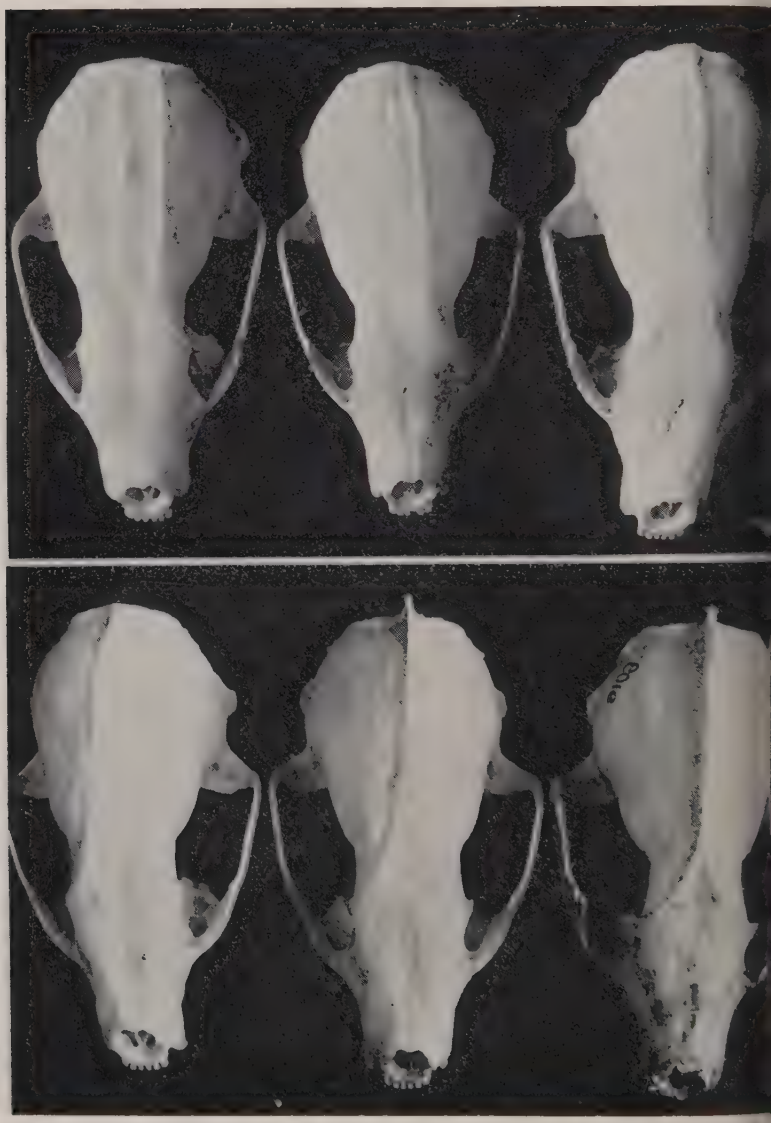
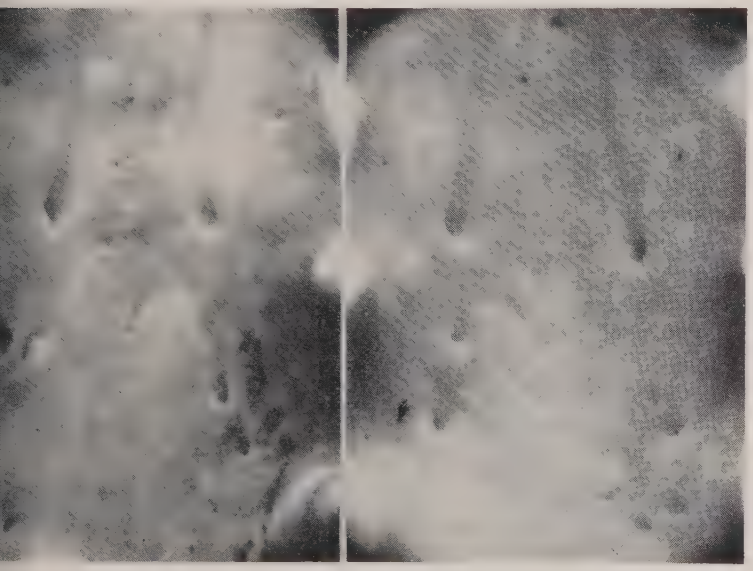


Figure 1. Skulls of female fisher showing development of sagittal cr
Immature, non-breeding females above, showing varying deg
of separation of the temporal ridges. Breeding females bel
showing range of development of sagittal crest from fusion
temporal ridges. Oldest on the right.

s had fused slightly. In each of these 16 skulls the maxillary-ine sutures were open anteriorly and, in most skulls, throughout length (Figure 2).



. 2. Portion of hard palate in female fisher skulls showing presence of maxillary-palatine suture in immature, non-breeding animal (left) and absence in mature, breeding animal (right).

These two criteria seemed sufficient to separate immature females breeding adults over 1 year old. A frequency distribution of the n of the sagittal crest was prepared for the 87 female skulls able. When arranged on the basis of 10-millimeter intervals re 3) it appeared that there were at least three age-groups in ample. The group of 29 specimens without sagittal crests and open maxillary-palatine sutures may be considered immature breeding animals less than 1 year old. Hall (1942) cited two ve females that bred at the age of 1 year. Since all 30 females e present sample that showed evidence of breeding exhibited al crests from 7 to 56 millimeters long and had completely fused lary-palatine sutures, it may be assumed that wild female fisher ally breed at the age of 1 year.

The total of 58 specimens with sagittal crests appears to fall at least two groups, or more if criteria in addition to length of

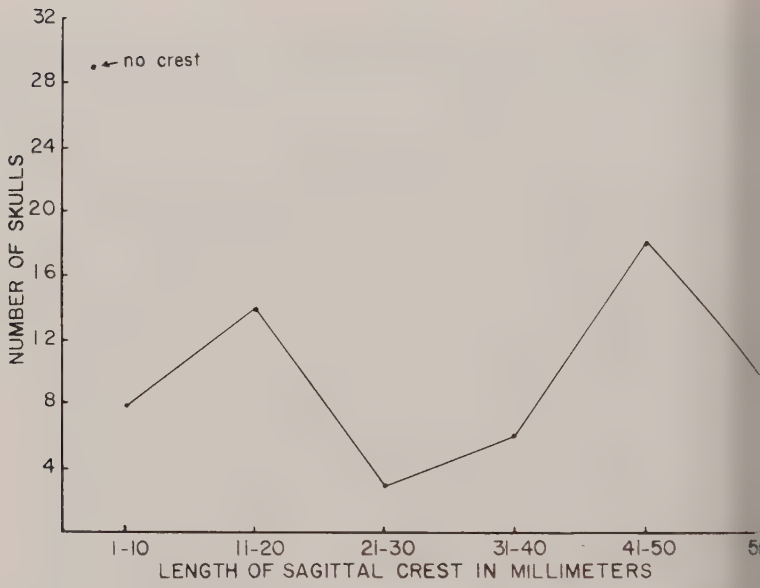



Figure 3. Frequency distribution of sagittal crest length in 87 female fi skulls.

crest are used. In those skulls with a crest length greater than millimeters, the crest shows a distinctly greater height anteriorly well as a knife-like edge. It is possible that those specimens v crests from 7 to 40 millimeters long may have been about 1½ y old when trapped. Those with knife-edged crests over 40 millime long may have been 2½ or more years old. The nine skulls v crests over 50 millimeters long may have represented older fema A few were relatively extreme in crest height and may have re sented the oldest, of indeterminate age. These latter skulls sho some indications of relatively greater natural tooth wear. Tooth w in general, could not be used as a good age criterion because high degree of abnormal wear and breakage in many skulls du trap chewing.

## IMPLANTATION AND PARTURITION

When implantation of the blastocyst takes place is not kn definitely, but two specimens taken in January (January 5 and yielded blastocysts when the uterine horns were flushed. A speci that was captured alive February 7 and that died in captivity Fe

5 had a corpus luteum in one ovary (the other ovary was lost), ielded no blastocysts. The uterine horns were in too bad a con- to section but were larger than those of females from previous ns. No embryos were found in this specimen but it is possible implantation may occur in New York State about this time. rs and Pearson (1943) found unimplanted blastocysts in females in February. The locality of collection was not stated but since pecimens came from the Hudsons' Bay Company, they may have taken considerably farther to the north. One of our specimens March 13, 1956 had a 75-millimeter (crown-rump) embryo presumably was not far from parturition. Hall (1942) gave late h or early April as the usual time of parturition in captivity n date for 22 females, March 31). Hamilton and Cook (1955) an instance where very young fisher were found in a nest in ild in mid-March in New York State.

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# EFFECT OF HIGH CARBOHYDRATE DIET AND EPINEPHRIN IN SALMON AND BROOK TROUT[1]

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ABSTRACT

A study of growth rates and tissue glycogen deposition in salmon m tained on a high carbohydrate diet reveals that the fish grew more ra on this experimental diet than on the high protein control diet, but that t was a corresponding increase in stored liver glycogen. The simultaneous a tion of epinephrine to the food just prior to feeding further accelerated gain in total body weight for the fish on the high carbohydrate diet and restored to normal the values of hepatic glycogen. Although fish on experimental diet had less muscle glycogen than the control fish, the addi of epinephrine did not affect these levels markedly. Epinephrine inject in large trout accelerated maturation of the gonads. It is suggested tha might be profitable in terms of both rate of weight increase and economy increase the proportion of carbohydrate in the diet of hatchery salmon, vided that epinephrine was administered simultaneously.

Carbohydrate digestion and utilization mechanisms of trout salmon have been shown to be essentially similar to those of hig animals when ingested carbohydrate levels are low. However, it been suggested that these mechanisms are inadequate to handle hig dietary levels of carbohydrate, with the maximum ingestion level be set as approximately 9 per cent digestible carbohydrate, and t levels beyond this result in "high-glycogen livers" with a concomit increase in mortality (Phillips *et al.*, 1945, 1948).

As the hormone epinephrine is well known for its glycogenol effect in mammals, it was decided to investigate the effect of a h carbohydrate diet administered simultaneously with epinephrine order to determine whether this hormone would prevent excess gly gen deposition in the liver and thereby make more carbohydr available to the fish for metabolic functions. An additional asp of the investigation is the possibility that, through the addition this inexpensive hormone, larger proportions of carbohydrate mi be included in the food used at State hatcheries. This would b considerable economy because carbohydrates are an inexpensive sou of energy as compared with fats and proteins (Phillips *et al.*, 194

## PRELIMINARY PROCEDURE

Preliminary experiments to test the response of hatchery to epinephrine were set up at the New York State Fish Hatchery

[1] The author wishes to acknowledge with thanks the active help and coop tion of Mr. Erwin Annis, New York State Fish Hatchery at Cambridge.

ridge, using four of their routine troughs for salmon. The fish obtained from the regular hatchery stock of landlocked salmon *o salar)* and measured approximately 4.5 centimeters in length e start of the experiment. The water at the hatchery comes springs, the average flow being 195 gallons per minute. The flow through individual troughs was 15 gallons per minute. The ge temperature of the water during the months of the experi- July and August 1953, was 56.9° F. Each trough was main- l under standard hatchery conditions and the fish were fed atchery diet of ground meat (60 per cent hog melts, 33 per cent 5 per cent fish meal, 2 per cent salt). The amount of feed per day was 9.8 per cent of the total body weight of the fish.

Trough 1 at the start of the experiment had 75 salmon with a ined weight of 258.7 grams; average individual weight was 3.5 s. One cubic centimeter of distilled water was mixed in daily 200 grams of the meat mixture.

Trough 2 at the start had 75 salmon with a combined weight of grams; average individual weight was 3.4 grams. Just prior to ig, one cubic centimeter of 1/10,000 epinephrine [2] was mixed h the meat (200 grams).

Troughs 3 and 4 were large outdoor troughs, each containing 14 brook trout *(Salvelinus fontinalis)*. The average weight of the in Trough 3 was 547.7 grams and for those in Trough 4 it was grams. These fish were also kept under standard hatchery condi- and fed the standard diet already described, but each trout in gh 4 was injected every second day with one cubic centimeter of 000 epinephrine. Each trout was caught with a net, held by an nt, and the hormone was injected into the dorsal musculature. 4 trout in Trough 3 were injected similarly with one cubic centi- of distilled water.

At the end of the experiment the fish were weighed, killed and ed. Reproductive organs of the large trout were photographed.

## PRELIMINARY FINDINGS

The experiment was concluded on August 3, 1953, at which time were 68 salmon left in the control Trough 1, their total weight 298 grams; average individual weight was 4.4 grams (Table 1). experimental Trough 2, there were 70 salmon remaining with l weight of 313 grams; average individual weight was 4.5 grams.

[2] rously supplied by Parke-Davis and Co. as adrenalin in hydrochloride. ic centimeter contains 25 micrograms of epinephrine.

TABLE 1. EFFECT OF EPINEPHRINE ON GROWTH OF SALMON AND TR

| Variable | July 13, 1953 | | August 8, 1953 | | Change in weight (per cent) | Mortal (per ce |
|---|---|---|---|---|---|---|
| | Number of fish | Average weight (grams) | Number of fish | Average weight (grams) | | |
| Control salmon*..... | 75 | 3.5 | 68 | 4.4 | +26 | 9 |
| Experimental salmon§ | 75 | 3.4 | 70 | 4.5 | +32 | 6 |
| Control trout*..... | 14 | 547.7 | 14 | 551.8 | + 0.7 | 0 |
| Experimental trout†.. | 14 | 513.0 | 14 | 503.4 | − 1.9 | 0 |

* Fed standard ground meat ration only.
§ Fed 100 micrograms of epinephrine mixed into 200 grams standard gro meat ration.
† Fed standard ground meat ration; 100 micrograms epinephrine inje every second day.

The percentage gain in weight for the fish fed epinephrine was per cent as compared with 26 per cent for the control fish. Both gro had low mortality rates with the greatest loss resulting from fish ju ing out of the troughs.

At the end of the experiment, the large trout in Trough 3 an average weight of 551.8 grams as compared with 547.7 gram the start. The experimental trout in Trough 4, however, had a decr in average weight from 513.0 to 503.0 grams. The loss in weigh the epinephrine-injected fish was 1.9 per cent, while the control gained 0.7 per cent. There was no mortality in either group.

After each injection of epinephrine the large trout displaye silver stripe along the back for approximately 12 hours (Figure This stripe represented the disappearance of pigment due to l contraction of melanophores in response to the diffusing epineph

Autopsy of the injected fish showed surprisingly well-develo reproductive tracts with large ovaries, free eggs and large soft ovid or with large soft testes (Figure 2). One hermaphrodite was fo with small hard ovaries and diffuse testes. The control trout not nearly so mature sexually, their gonads still being small and h The thymus glands of the fish given epinephrine were consider smaller and paler than those of the control fish.

## DISCUSSION OF PRELIMINARY EXPERIMENTS

These pilot experiments showed that, for salmon, the add

re 1. Trout after injection of 100 micrograms of epinephrine. Note local disappearance of pigment.

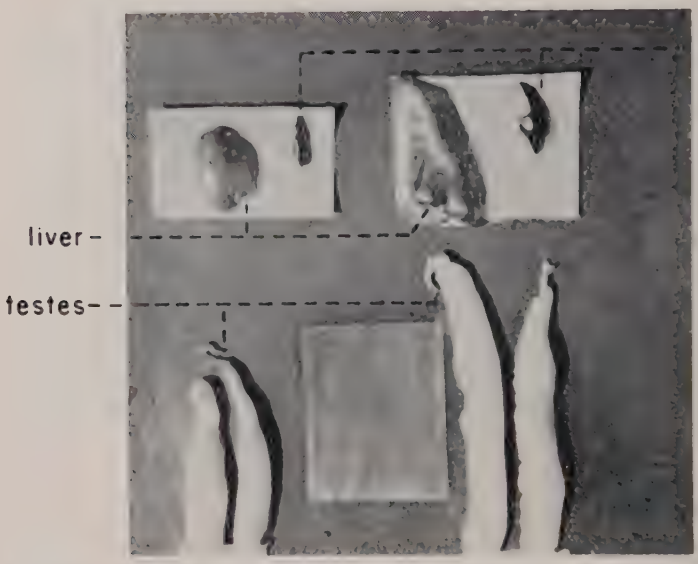
pinephrine to a diet consisting mainly of protein was well tolerated he fish and even accelerated their rate of growth slightly.

Injection of epinephrine into the large trout, also maintained a protein diet, was again well tolerated, but there was a slight ght loss probably due to increased carbohydrate metabolism without eased carbohydrate intake. One may infer that the endogenous ephrine levels in the young salmon were not high enough to per- optimum utilization of the available carbohydrate; thus additional ephrine was able to accelerate growth. In the older trout, how- , there was probably enough epinephrine available for the break- n of the small proportion of carbohydrate obtained in the diet. itional epinephrine may, therefore, increase growth under condi- s represented by the young salmon and decrease weight under e represented by the trout.

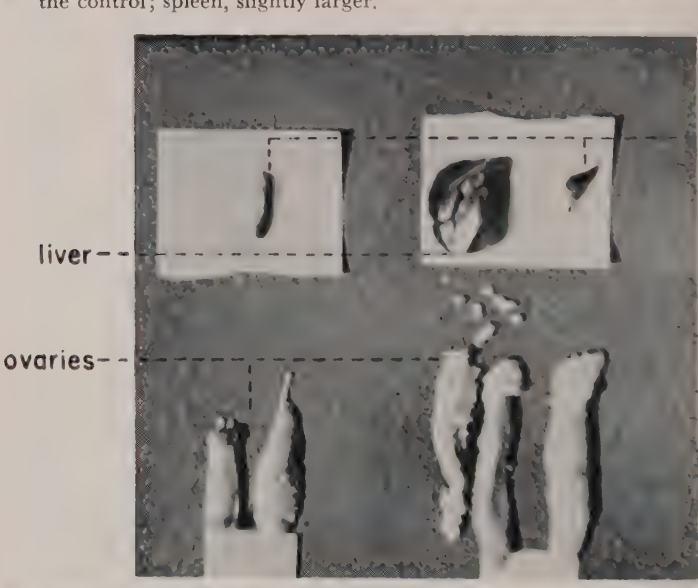
The validity of these assumptions was tested partially in the next s of experiments, performed the following summer, when large unts of carbohydrate were added to the basic protein diet and genous epinephrine was administered simultaneously. The glycogen entration in liver and muscle was measured and this, together weight records, served as an indicator of the effectiveness of ephrine in regulating glycogen storage and utilization in salmon.

## PROCEDURE

The fish were divided into two groups, the control group con- g of 25 salmon with a total weight of 1,347 grams and an average




a. Males: testes and liver of injected trout appear much larger than the
the control; spleen, slightly larger.




b. Female: note large ovaries and free eggs from experimental trout;
appears contracted compared with that of control. (Liver of control
inadvertently omitted from photograph.)

Figure 2. Appearance of internal organs of trout injected with epine
compared with those of control fish. In each case: organs on
are those of experimental fish; organs on left, those of contr

idual weight of 53.9 grams ±3.8". The 25 experimental salmon ıed 1,421 grams with an average weight of 56.8 grams ±4.2. ing on June 13, 1954, both groups were fed a mixture consisting ) per cent ground meat (the same hatchery mixture described e) and 25 per cent Cortland No. 6a diet[1]. The experimental ) received 4 cubic centimeters of 1/10,000 epinephrine carefully d into the one-quarter pound of feed mixture given to the fish day. The control group recevied an equivalent volume of distilled r mixed into the food, the stirring being equally thorough.

These fish were maintained in large covered outdoor troughs r standard hatchery conditions. The salmon were killed over the d from August 3 to September 7, 1954, and liver and muscle slices analyzed quantitatively for glycogen, using the anthrone reagent rris, 1948). A logarithmic curve was constructed of the values glycogen standard as read on a Roux photometer, and the experi- al values were derived from this curve. For each chemical mination, two experimental fish, two control fish and one fish ı at random from the routine hatchery troughs were killed. Dupli- determinations were obtained from each specimen for each tissue ′zed and the final figure was derived from the mean of each of determinations. Any wide variation between these duplicates ted in both figures being discarded.

## FINDINGS

The experimental fish were much better in general appearance the control fish when both groups were maintained on the high )hydrate diet. The control fish were somewhat bloated and their nal pigmentation uneven. The color of the epinephrine-adminis- salmon was much more evenly dsitributed and they maintained ıutiful silvery blue until death, at which time they became green. about 15 minutes dark circles appeared dorsally and laterally, unded by light areas apparently drained of pigment. On autopsy, ivers of the experimental fish were slightly redder than those e controls which were paler and somewhat blotched.

Chemical analyses showed that the control fish, fed a high car- drate diet, had deposited considerably more glycogen in the liver had the hatchery fish fed the high protein diet. The livers of

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ndard error.

nprising 24 per cent each of cottonseed meal and wheat middlings, 48 cent fish meal, and 4 per cent salt.

the experimental fish, where epinephrine supplemented the high car hydrate diet, had slightly less glycogen accumulated than did th of the hatchery fish. Muscle glycogen was slightly less concentra in the experimental fish than in the controls, but both groups h muscle glycogen values considerably below the concentrations fou in the hatchery fish (Table 2 and Figure 3).

Table 2. Effect of High Carbohydrate Diet plus Epinephrine u Liver and Muscle Glycogen in Salmon (August 3 to Sept ber 7, 1954)

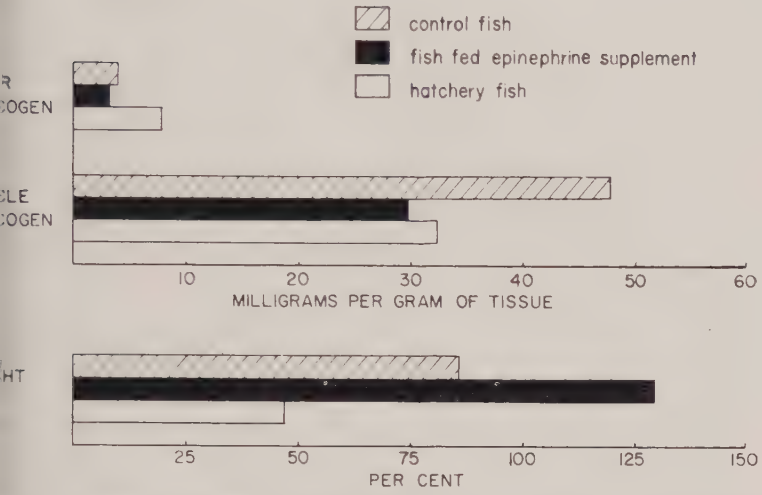
| Variable | Number of fish | Average weight (grams) | | Change in weight (per cent) | Mortality (per cent) | Glycogen* (milligrams per gram of tissue) | |
|---|---|---|---|---|---|---|---|
| | | At start | At end | | | Liver | Musc |
| Control salmon§ | 25 | 56.8 | 105.6 | + 86 | 0 | 47.7 (±2.1) | 4.0 (± |
| Experimental salmon† | 25 | 53.9 | 122.4 | +127 | 0 | 29.7 (±1.8) | 3.1 (± |
| Hatchery salmon‡ | 12 | 55.0° | 80.9 | + 47 | 3.7• | 32.4 (±2.2) | 7.9 (± |

* Figures in parentheses represent standard error.
§ Fed ration of standard ground meat (75 per cent) and dry meal (25 cent).
† Fed 100 micrograms of epinephrine mixed into ¼ pound of above rat
‡ Fed standard hatchery diet of ground meat (85 per cent) and dry m (15 per cent). Control and experimental fish taken from this group start of experiment.
° Weight range at time of separating fish was 45 to 65 grams per fish.
• Data from Cambridge Fish Hatchery records for July 1954.

The percentage gain in weight for those fish fed the high c bohydrate diet together with the epinephrine was considerably grea than that for the fish maintained only on either the high carbohydr or the high protein diet. There was no mortality in either the con or experimental troughs.

## DISCUSSION

Endocrine control of carbohydrate metabolism in mammal vested mainly in the adrenal medulla with its secretion of epinephr and in the pancreatic secretion, insulin. These two hormones ma tain a gradient between the levels of stored glycogen and circula blood glucose. The adrenal-cortical hormones also influence the s age and utilization of carbohydrate but probably mainly under m stressful conditions when glyconeogenesis is likely to occur. In




re 3. Relative amounts of glycogen in tissue and relative weight gains for three groups of salmon fed high carbohydrate diets.

control of blood sugar by insulin is markedly similar to the hanism found in mammals although the rate of the reactions ears to be slower than in warm-blooded animals (Phillips *et al.*, 5). The diffuse nature of the adrenal glands in fish makes it dif- t to determine the effects of surgically removing them; thus, oration of the role of epinephrine was limited in this study to ng epinephrine to the normal physiological level.

All these experiments must be considered as preliminary in nature. n the results obtained it would seem that epinephrine acts to ease fish liver glycogen, or, strictly speaking, to prevent the ected rise in liver glycogen in fish fed a high carbohydrate diet. his failure to deposit excess hepatic carbohydrate is accompanied considerable increase in the weight of the fish, it may be inferred the additional carbohydrate ingested is being used for growth enegry requirements and that this high level of carbohydrate zation is not possible with the available endogenous epinephrine. increased oxidation of carbohydrate may be due to stimulation nsulin secretion by the excess epinephrine, or it may be the direct t of additional glycogenolysis with a resulting increase in the lable glucose (Law of mass action).

The marked increase in rate of sexual maturation shown by the ted trout in the preliminary series of experiments suggests that

epinephrine may stimulate the anterior pituitary gland to rel gonadotrophins and thereby hasten the development of the reproc tive system. A similar mechanism for the release of anterior pitui secretions has been postulated in higher animals under certain c ditions by Long and his collaborators (Long and Fry, 1945; McDerr *et al.*, 1950). Hasler *et al.* (1939) and Robertson and Rinfret (19 have shown that secretions of the anterior pituitary gland c marked enlargement of the gonads with accelerated gametogenesi fish.

The traditional effect of epinephrine on pigmentation was matically seen in the injected trout, where the silver line represe the withdrawal of pigment into the contracted melanophores. It w be interesting to determine whether there is an additional indi effect of epinephrine on coloration via stimulation of the pitui hormone, intermedin.

From a practical viewpoint the problem posed by McCay *e* (1927) is still valid. This is whether, once their protein needs growth are supplied, fish can derive energy from an equal amo of carbohydrate which is not only cheaper than protein but prob better as an energy source. The excellent work done by Tuni Phillips and others has shown that high levels of carbohydrate do function as available energy sources, but rather increase the mort due to pathological glycogen deposition in the liver. From the pre study, it seems possible that the addition of small amounts of ep phrine to the diet of hatchery fish will enable them to use efficie the additional carbohydrate without any apparent deleterious eff If the rate of destruction of epinephrine once it is mixed with the is determined and the most efficient time and concentration fac derived, it is possible that hatchery diets may productively contain siderably more carbohydrate when epinephrine is simultaneously minisistered. As this hormone is comparatively inexpensive an needed in minute amounts, this may have economic advantages for feeding of large numbers of trout or salmon.

## CONCLUSIONS

A high carbohydrate diet will increase the weight of salmon the amount of carbohydrate deposited in the liver beyond the va characteristic of salmon maintained on a high protein diet. B on the experiments described, addition of small amounts of epineph to a high carbohydrate diet not only results in a still further gai total body weight but restores liver glycogen levels to normal.

Salmon maintained on a high carbohydrate diet have lower levels uscle glycogen than salmon fed a high protein diet. Addition of phrine to the high carbohydrate diet further reduces the level of le glycogen.

There were no mortalities in the fish fed the high carbohydrate with or without the supplementary epinephrine, for the duration e experiment.

Injections of epinephrine accelerate sexual maturation in trout.

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# PHEASANT USE OF FIELD BORDERS IN WESTERN NEW YOR

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ABSTRACT

Observations made on 70 miles of field borders on a 3,500-acre are Monroe County were analysed to determine the degree to which type, wi density, and species composition affected their degree of use by pheasa Records of pheasant use totaled 211 during the summer and 1,501 during winter. Density of cover seemed to be the most important factor influen pheasant usage. Of the various species providing dense cover, grape outstanding and seemed to merit consideration for encouragement.

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In 1949 certain studies of pheasant ecology were undertaken o 3,500-acre tract in Monroe County. Known as the Henrietta a it is roughly typical of the intensively farmed land of the Lake Pl region which includes the best pheasant range in the State.

From 1951 through 1953, the 70 miles of field borders on the a were covered during summer and winter as part of the seasonal c suses, and many observations on their use by pheasants were ma The purpose of this paper is to examine these records of usage in r tion to the various types of field borders.

## PROCEDURE

The field borders were arbitrarily broken down into five cla as follows:

Class I (mainly herebaceous)
Class II (mixed herbs and shrubs)
Class III (mixed herbs and trees)
Class IV (mainly shrubs)
Class V (mixed shrubs and trees)

Further subdivisions in each class were made as to width of the bo (5 feet and under, 6 to 19 feet, and over 20 feet); density of gro (sparse, medium, and dense); and the dominant herbaceous woody plant species. A detailed description of each recogniz separate unit was prepared which, in addition to the above noted it

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[1] A contribution of Federal Aid in Fish and Wildlife Restoration Pr W-26-R.

ded the slope, exposure (compass direction), relation to ditches, lanes and property lines.

These units were plotted on a detailed habitat map and numbered ater identification. Since the habitat map had been drawn to scale the Town property map and habitat data superimposed from a bination of aerial photographs and field surveys, the unit lengths ie field borders were measured directly from the map, but they also counter-checked by pacing.

For each unit, evidences of use by pheasants (sight, track, dust- dropping and feather observations) were recorded for both ds in summer and adults in winter and thus could be correlated the field border characteristics under consideration. These rec- were gathered by two men walking the field borders of the area, on each side. Two complete coverages were made in winter and in summer.

The percentage of occurrence on the area was calculated for each of field border and for the various subdivisions according to h, density, and composition in each class.

The importance to pheasants of a given type of border was con- ed to be the relationship between its percentage of occurrence the degree of pheasant use recorded for it. Expressed as a ratio, has been termed the "use factor".

## FINDINGS

The 70 miles of field borders on the Henrietta area were found bdivide into 351 separate units that differed enough from adjoin- nits to merit recognition. Over 60 per cent of the units varied 300 to 1,000 feet in length. Only 12 shorter ones were considered ately. Similarly, 12 units of over one-half mile in length were ded. All but one of the latter were in Class I, and all formed way boundaries. The relative occurrence of the various classes ld borders on the area is given in Table 1, and in Table 2 are nted the corresponding incidence of pheasant sign and degree of ant use.

Comparison of the calculated use factors indicates that during ummer Class II borders were used in excess of their occurrence, es III and V about equally to their occurrence, and Classes I and ppreciably below their occurrence. During the winter months elationship changed. The degree of use for Class IV was very greater than its relative occurrence; that for Classes V and II omewhat greater, and that for Classes III and I considerably less.

Table 1. Relative Occurrence of Field Borders on the Henri Area

| Class | Composition | Number of units | Total length in feet | Percentag of occurrenc |
|---|---|---|---|---|
| I | Mainly herbs... | 123 | 125,835 | 34.3 |
| II | Herbs and shrubs | 74 | 82,225 | 22.5 |
| III | Herbs and trees | 36 | 37,190 | 10.2 |
| IV | Mainly shrubs | 22 | 25,080 | 6.8 |
| V | Shrubs and trees | 96 | 95,785 | 26.2 |
| Total..... | | 351 | 366,115 | 100.0 |

Table 2. Incidence of Pheasant Sign and Relative Degree of Pheas Use for Various Classes of Field Borders on the Henri Area from 1951 to 1953

| Class | Incidence of sign | | Use factor* | Rank |
|---|---|---|---|---|
| | Number | Per cent | | |
| | | Summer | | |
| I | 58 | 27.5 | 0.80 | 4 |
| II | 61 | 28.9 | 1.28 | 1 |
| III | 22 | 10.4 | 1.02 | 3 |
| IV | 10 | 4.7 | 0.69 | 5 |
| V | 60 | 28.5 | 1.09 | 2 |
| Total..... | 211 | 100.0 | xxx | xxx |
| | | Winter | | |
| I | 149 | 9.9 | 0.29 | 5 |
| II | 466 | 31.0 | 1.38 | 3 |
| III | 50 | 3.3 | 0.32 | 4 |
| IV | 242 | 16.1 | 2.37 | 1 |
| V | 594 | 39.7 | 1.52 | 2 |
| Total..... | 1,501 | 100.0 | xxx | xxx |

* Ratio of percentage of occurrence of a class (from Table 1) to the centage incidence of pheasant sign in it.

Examination of various factors as clues to these seasonal pr ences suggested that density of the cover might be important, at during the winter period. The relative occurrence of the three de of density recognized is given in Table 3 for each class of borde

Comparison of these data with those in Table 2 indicates a direct relationship between cover density in field borders and use by pheasants during the winter months, with the class provi the greatest density being the most used. No such direct relation

E 3. RELATIVE OCCURRENCE OF THREE DEGREES OF DENSITY IN THE VARIOUS CLASSES OF FIELD BORDERS ON THE HENRIETTA AREA

| SS | Percentage of occurrence | | | |
|---|---|---|---|---|
| | Sparse | Medium | Dense | Total |
| | 53.4 | 34.6 | 12.0 | 100.0 |
| | 3.9 | 57.6 | 38.5 | 100.0 |
| | 57.9 | 24.9 | 17.2 | 100.0 |
| | 0.0 | 47.1 | 52.9 | 100.0 |
| | 5.7 | 41.7 | 52.6 | 100.0 |
| ... | 26.6 | 41.5 | 31.9 | 100.0 |

he summer months is shown. Examination of the total number of sants and pheasant signs observed further demonstrates the impor- e of cover density. Of the 1,501 winter records, only 2.5 per cent in units of sparse density, while 30.7 per cent were in medium e and 66.8 per cent in dense units. This represented a very low actor for the sparse cover, but the dense units were used at a rate than double that of their occurrence on the area. The 211 ner brood records also indicated greater use of the denser cover, with sparse and medium units falling only slightly below a rate alent to their occurrence.

Tabulation of field border widths showed that in each class some thirds of the units fell in the middle width group of 6 to 19 feet the remainder about equally divided between the wider and wer classifications. No indication of differential use by width discernible either in the total records or in those for any one class. vise, no influence from slope, exposure or relation to ditches or lanes could be demonstrated in the data.

Aside from units that were made up predominantly of grasses or nrod, the borders in general tended to be of mixed composition, ugh for short distances one species might be dominant. Among oody plants the most frequent were raspberry, gray dogwood, elm, , cherry, and sumac. The proportions of the units in each class hich these plants occurred as one of the dominant species are n in Table 4.

No direct relation between pheasant use and plant species occur- n the field borders could be demonstrated for the summer months. during the winter there was a high relationship between pheasant nd the borders containing grape, in particular, as well as elm herry. However, since these units, in nearly all cases, were also

those classed as having high density, it is difficult to separate the im tance of density from that of plant composition. Other factors also involved, of which the primary one appeared to be the rela of the field border to good winter feeding grounds. Any dense bo unit near standing corn was used extensively. At the same time t dense borders containing grape which provided food were comm used almost regardless of their relation to other winter food source

## DISCUSSION

During the summer months the distribution of the pheasant p lation as a whole was relatively uniform over the area. Corresp ingly, opportunity for the use of the different types of field borders about equal. The possible exception was Class I (mainly he which predominated along the roadsides where disturbance human activity would have been most apt to drive the birds a Based on field observations, the primary uses made of the field bor by broods were for dust-bath sites, shade on hot days, and occasio for protection from rain. Hedgerows did not appear to be so regularly as either travel lanes or escape cover except where ne field vegetation was sparse. Therefore, the observed rates of use the brood period appear quite logical. Class II (herbs and shr had the most sites that provided both shade and good dust-bath s followed by Class V (shrubs and trees) and Class III (herbs trees). The units composed mainly of herbs provided few dust- sites and not very satisfactory shade, and appeared to be used ju additional meadowland for feeding. The units containing m shrubs provided an excess of shade to the point where the ground often too damp for dust baths.

In winter the field borders appeared to play a very impo role in pheasant life. As the cover in the croplands became sc the hedgerows were used more and more as travel lanes, escape c and for shelter from the weather. Along with this, signs that phea were feeding in the hedgerows also became more frequent. observed rates of use for the various classes followed the chang pheasant habits, with the units providing the densest cover and most potential foods receiving the greatest use. Meanwhile, the that were mainly herbs, or herbs and trees, offered little in the of meeting pheasant needs in winter and were little used.

The presence of other sources of winter food was also a fa Those hedgerows near good winter feeding grounds in the for standing corn, small grain stubble, and beans received more-t

ıge use. Again, density appeared to be important, but hedgerows edium and low density were more heavily used where near such sources than elsewhere on the area.

Borders in which grape was a major component were favored by sants both for shelter and for winter food. Thus this species merits deration for planting and encouragement in pheasant range.

## CONCLUSIONS

In summer, field borders are used by pheasants, especially broods, ly for dust-bath sites, shade, and protection from rain. Most ers that provide some woody growth are acceptable. During the er the field border becomes even more important, with the denser erows near good feeding grounds being the most valuable. Of several woody plants predominating in the units studied, grape ars especially worthy of encouragement in New York hedgerows ıse its provides both cover density and winter food.

# GENERAL NOTES

## EFFECT OF PRESSURE ON THE ASPHYXIAL OXYGEN LEVEL F BROWN TROUT

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Studies conducted in the Rome Laboratory in 1956-57 failed to s any significant variation in the residual oxygen content of the water at t over time for brown trout when subjected to an increase in pressure. C parison was made between data for atmospheric pressure (approximatel pounds per square inch) and a pressure of about 40 pounds per square i the additional 25 pounds being induced in a closed pressure chamber. latter pressure would correspond roughly to that to which fish would be jected at a depth of 57 feet. An increase in temperature from 60° to 65 failed to increase the differences to any appreciable extent.

It was concluded that, at least for a fish in which the air bladder o to the oesophagus such the brown trout, pressure produced by depth s unlikely to change the level of concentration at which they are able to ex oxygen from the water previous to turn-over.

## NOTES ON ELECTRIC FISHING TECHNIQUES

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The effects of 230-volt alternating and direct currents on fish were pared under favorable circumstances in 600-acre Lamoka Lake (Sch County) in water having a resistivity of 5,500 ohms per centimeter at 70° F. The electric device used consisted of a large boat with two pended cable electrodes (Loeb, 1957). The test was carried out at night.

Direct current failed to draw fish to the anode regardless of boat sp and was relatively ineffective in narcotizing fish. Large carp and pick for example, were able to swim from the field after touching the an Alternating current of similar voltage effectively paralyzed fish of all By visual estimate, the effectiveness of alternating over direct current w a ratio of 50 to 1.

Limited daylight tests with an echo sounder in the same lake (on No ber 13 when the surface water temperature was 55° F.) revealed the pres of a "layer" of fish, of unknown size and species, at depths of 7 to 15 The fish were present at this level in all parts of the lake having a dep 20 feet or more.

The tests were conducted in conjunction with development of an elect bottom trawl intended for collecting fish. Fish revealed by such a sou probably could be captured only by a midwater trawl drawn at the de depth. A combination of adjustable trawl, echo sounder, and telemeter registering trawl depths) would probably be necessary for efficient operati

### LITERATURE CITED

Loeb, Howard A. 1957. Night collection of fish with electricity. New Fish and Game Jour. 4(1): 109-118.